ROSEN'S
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Concepts and Clinical Practice

9th Edition

Rosen's Emergency Medicine

Concepts and Clinical Practice

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MV

It is both humbling and a privilege to be associated with this text and those who started it all— Rosen, Marx, Walls, and Hockberger—the founders of our discipline.

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Preface to the Ninth Edition

When we began planning for this ninth edition, we challenged ourselves to make substantial and meaningful improvements to a book that has become the trusted standard in our field. With broad and rapid changes occurring in health care and information sciences, we recognized that relevance is not an accidental or passive concept. To advance in relevance and consolidate the book's position as the defining reference in our specialty, we carefully and deliberately undertook bold changes that we know make the book at once fresh, directive, and current in a way we have never before dared.

First, we created a substantially enhanced role for our editors, one that would demand a great deal more of their time, creativity, and energy. This helped us build a substantially different team of editors, a perfectly balanced blend of those with great experience with prior editions and those who would bring new ideas and challenge our assumptions. Ron Walls was asked to serve as Editor-in-Chief, with Bob Hockberger in his long-standing role as senior editor. Marianne Gausche-Hill, a highly respected academic emergency physician with service as editor on four previous editions, stepped up to complete our senior editorial ranks. At the editor level, Dr. Andy Jagoda returns and is joined by six brilliant new editors drawn from academic programs from coast to coast—Drs. Katherine Bakes, Jill Baren, Timothy Erickson, Amy Kaji, Michael VanRooyen, and Richard Zane. This dynamic and innovative editorial team has dramatically redrawn our text's blueprint by preserving what has served our readers the best, such as well-written discussions of the pathophysiologic basis of illness and injury, while moving in entirely new directions in providing pithy, clear, and succinct recommendations for diagnosis and treatment.

We collectively determined that all references prior to 2010 have been sufficiently long in the public domain that they no longer warrant citation. The infrequent exception to this is for guidelines that were issued in 2007 or later and have not been reissued or supplanted since. Strict adherence to our referencing policy required authors to diligently provide well-researched and detailed updates to their chapter content, based on only the most recent and relevant medical literature. In cases in which the literature is controversial or unclear, we have used the combined experience and expertise of our authors and editors to present cogent analyses of diagnostic and treatment options, make specific recommendations, and give the reader clear indications of the preferred actions. This makes the book much more immediately relevant for emergency clinicians. We recognize that emergency medicine is practiced by specialist emergency physicians, other physicians, residents and other trainees, and a variety of nonphysician practitioners, so were careful to ensure that we are addressing all these groups with the same concise, highest quality information and recommendations.

We revisited page counts for every chapter, adjusting allocations where indicated, and added new chapters on several important topics. We focused anew on consistency and redundancy, enhancing the former and minimizing the latter. We moved some chapters to online access only, allowing us to add new topics of interest, such as drug therapy for older patients, and have provided a rich array of dynamic videos and images, especially in emergency ultrasound. We substantially expanded and reorganized the pediatric emergency medicine section, introducing dedicated pediatric chapters on airway management, procedural sedation, and drug therapy. We introduced significant new material on emergencies in the pregnant woman, the patient with cancer, and a variety of other highly important clinical conditions. And, in every possible case, we insisted on adherence to referencing and writing requirements, a focus on relevant directive information, and appropriate use of prose and illustrations to provide the perfect balance of depth, breadth, and ready accessibility.

We are enormously proud of the result, a different, more readable "*Rosen,*" preserving the gravitas earned over 30 years as the most important book in our specialty while embracing the modern era of emergency medicine practice and research and an entirely new generation of learners and practitioners. For those who have owned prior editions, we appreciate your loyalty over so many years and hope to reward it with a significantly improved and useful companion for your continuing learning and practice of this great specialty. For our newer readers, welcome, and thank you for inspiring us to make significant changes to an iconic and timeless part of our academic heritage.

Ron M. Walls
Robert S. Hockberger
Marianne Gausche-Hill

How This Medical Textbook Should Be Viewed by the Practicing Clinician and Judicial System

The editors and authors of this text strongly believe that the complex practice of medicine, vagaries of human diseases, unpredictability of pathologic conditions, and functions, dysfunctions, and responses of the human body cannot be defined, explained, or rigidly categorized by any written document. *Therefore, it is neither the purpose nor intent of our textbook to serve as an authoritative source on any medical condition, treatment plan, or clinical intervention, nor should our textbook be used to rigorously define a standard of care that should be practiced by all clinicians.*

Our written word provides the physician with a literature-referenced database and a reasonable clinical guide combined with practical suggestions from individual experienced practitioners. We offer a general reference source and clinical road map on a variety of conditions and procedures that may confront emergency clinicians who are experienced in emergency medicine practice. This text cannot replace physician judgment, cannot describe every possible aberration, nuance, clinical scenario, or presentation, and cannot define rigid standards for clinical actions or procedures. *Every medical encounter must be individualized, and every patient must be approached on a case-by-case basis.* No complex medical interaction can possibly be reduced to the written word. The treatments, procedures, and medical conditions described in this text do not constitute the total expertise or knowledge base expected to be possessed by all emergency clinicians. Finally, many of the described complications and adverse outcomes associated with implementing or withholding complex medical and surgical interventions may occur, even when every aspect of the intervention has been standard or performed correctly.

The editors and authors of Rosen's Emergency Medicine: Concepts and Clinical Practice, Ninth Edition

SECTION ONE
Critical Management Principles

CHAPTER 1
Airway

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PRINCIPLES

Background

Airway management is the cornerstone of resuscitation and is a defining skill for the specialty of emergency medicine. The emergency clinician has primary airway management responsibility, and all airway techniques lie within the domain of emergency medicine. Although rapid sequence intubation (RSI) is the most commonly used method for emergent tracheal intubation, emergency airway management includes various intubation techniques and devices, approaches to the difficult airway, and rescue techniques when intubation fails.

Anatomy, Physiology, and Pathophysiology

The decision to intubate should be based on careful patient assessment and appraisal of the clinical presentation with respect to three essential criteria: (1) failure to maintain or protect the airway; (2) failure of ventilation or oxygenation; and (3) the patient's anticipated clinical course and likelihood of deterioration.

Failure to Maintain or Protect the Airway

A patent airway is essential for adequate ventilation and oxygenation. If a patient is unable to maintain a patent airway, the airway should be established by using airway maneuvers such as repositioning, chin lift, jaw thrust, or insertion of an oral or nasal airway. Likewise, the patient must be able to protect against the aspiration of gastric contents, which carries significant morbidity and mortality. Historically, the presence of a gag reflex has been advocated as a reliable indicator of the patient's ability to protect the airway, but this has been definitively proven to be unreliable because the gag reflex is absent in 12% to 25% of normal adults, and there is no evidence that its presence or absence corresponds to airway protective reflexes or predicts the need for intubation. The patient's ability to swallow or handle secretions is a more reliable indicator of airway protection. The recommended approach is to evaluate the patient's level of consciousness, ability to phonate in response to voice command or query, which provides information about the integrity of the upper airway and level of consciousness, and ability to manage his or her own secretions (eg, pooling of secretions in the oropharynx, absence of swallowing spontaneously or on command). In general, a patient who requires a maneuver to establish a patent airway or who easily tolerates an oral airway requires intubation for airway protection, unless there is a temporary or readily reversible condition, such as an opioid overdose.

Failure of Ventilation or Oxygenation

Gas exchange, both oxygenation and removal of carbon dioxide, is required for vital organ function. Ventilatory failure that is not reversible by clinical means or persistent hypoxemia despite maximal oxygen supplementation is a primary indication for intubation. This assessment is clinical and includes an evaluation of the patient's general status, oxygen saturation by pulse oximetry, and ventilatory pattern. Continuous capnography also can be helpful but is not essential if oximetry readings are reliable. Arterial blood gases (ABGs) generally are not required to determine the patient's need for intubation. In most cases, clinical assessment, including pulse oximetry with or without capnography, and observation of improvement or deterioration in the patient's clinical condition lead to a correct decision. ABG results are rarely helpful, are time-consuming to obtain, and may be misleading, causing a false sense of security and delay in intubating a deteriorating patient. If obtained, they should be interpreted carefully in the context of the patient's clinical status. Patients who are clinically improving despite severe or apparently worsening ABG alterations may not require intubation, whereas a rapidly tiring asthmatic may require intubation, even though ABG values are only modestly disturbed.

The need for prolonged mechanical ventilation generally mandates intubation. An external mask device, continuous positive airway pressure (CPAP) and bi-level positive airway pressure (BL-PAP), have all been used successfully to manage patients with exacerbations of chronic obstructive pulmonary disease (COPD) and congestive heart failure, obviating the need for intubation (see Chapter 2) but, despite these advances, many patients who need assisted ventilation or positive pressure to improve oxygenation require intubation.[1,2]

Anticipated Clinical Course

Certain conditions indicate the need for intubation, even without an immediate threat to airway patency or adequacy of ventilation and oxygenation. These conditions are characterized by a moderate to high likelihood of predictable airway deterioration or the need for intubation to facilitate a patient's evaluation and treatment. Intubation may be indicated relatively early in the course of certain overdoses. Although the patient initially may be protecting the airway and exchanging gas adequately, intubation is advisable to guard against the strong likelihood of clinical deterioration, which can occur after the initial phase of care when the patient is no longer closely observed. A patient who has sustained significant multiple traumatic injuries may require intubation, even if the patient is ventilating normally through a patent airway and has adequate oxygen levels. For example, a multiple trauma

patient with hypotension, open femur fracture, and diffuse abdominal tenderness warrants early intubation, even if the patient is initially awake and alert, without airway injury or hypoxemia. Active resuscitation, pain control, need for invasive procedures and imaging outside of the emergency department (ED), and inevitable operative management dictate the need for early airway control. In addition, a patient with penetrating neck trauma may have a patent airway and adequate gas exchange. Nevertheless, early intubation is advisable when there is evidence of vascular or direct airway injury because these patients tend to deteriorate, and increasing hemorrhage or swelling in the neck will compromise the airway and confound later attempts at intubation.

The common thread among these indications for intubation is the anticipated clinical course. In each case, it can be anticipated that future events may compromise the patient's ability to maintain and protect the airway or ability to oxygenate and ventilate, and waiting until these occur may result in a difficult airway.

Identification of the Difficult Airway

In most patients, intubation is technically easy and straightforward. Although early ED-based observational registries reported cricothyrotomy rates of about 1% for all intubations, more recent studies have shown a lower rate, less than 0.5%.[3] As would be expected with an unselected, unscheduled patient population, the ED cricothyrotomy rate is greater than in the operating room, which occurs in approximately 1 in 200 to 2000 elective general anesthesia cases.[4] Bag-mask ventilation (BMV) is difficult in approximately 1 in 50 general anesthesia patients and impossible in approximately 1 in 600. BMV is difficult, however, in up to one-third of patients in whom intubation failure occurs, and difficult BMV makes the likelihood of difficult intubation four times higher and the likelihood of impossible intubation 12 times higher. The combination of failure of intubation, BMV, and oxygenation in elective anesthesia practice is estimated to be exceedingly rare, roughly 1 in 30,000 elective anesthesia patients.[4] These numbers cannot be extrapolated to populations of ED patients who are acutely ill or injured and for whom intubation is urgent and unavoidable. Although patient selection cannot occur, as with a preanesthetic visit, a preintubation analysis of factors predicting difficult intubation gives the provider the information necessary to formulate a safe and effective plan for intubation.

Preintubation assessment should evaluate the patient for potential difficult intubation and difficult BMV, placement of and ventilation with an extraglottic device (EGD; see later discussion), and cricothyrotomy. Knowledge of all four domains is crucial to successful planning. A patient who exhibits obvious difficult airway characteristics is highly predictive of a challenging intubation, although the emergency clinician should always be ready for a difficult to manage airway, because some difficult airways may not be identified by a bedside assessment.[5]

Airway difficulty exists on a spectrum and is contextual to the provider's experience, environment, and armamentarium of devices. Airways predicted to be difficult when using a traditional laryngoscope may not prove to be difficult when a videolaryngoscope is used. Some patients may have a single minor anatomic or pathophysiologic reason for airway difficulty, whereas others may have numerous difficult airway characteristics. Although both sets of patients represent potential intubation challenges, the latter group would likely have crossed a threshold beyond which neuromuscular blockade would be avoided because a so-called can't intubate and can't oxygenate failed airway may ensue. In these cases, a preferred approach would include topical anesthesia, parenteral sedation, and intubation without the use of a neuromuscular blocking agent (NBMA). Occasionally, RSI remains the preferred method, despite a concerning bedside assessment, when it is part of a planned approach to the difficult airway. This may include use of a double setup, in which a rescue approach, such as cricothyrotomy, is simultaneously prepared in the event of intubation failure. Regardless of the results of a reassuring bedside assessment for airway difficulty, significant challenges may be encountered with intubation and bag mask ventilation and the clinician must be prepared for unanticipated difficulty.

Difficult Direct Laryngoscopy: LEMON

Glottic visualization is paramount in emergency airway management. With direct laryngoscopy (DL), if the vocal cords can be seen (Cormack and Lehane [CL] grade I or II view; Fig. 1.1), the chance of intubation success is high. However, when the glottic aperture cannot be visualized (CL grade III or IV), intubation success is less likely. Very few of the difficult airway markers thought to limit DL access have been scientifically validated, yet applying them in combination can provide a reasonable assessment of anticipated airway difficulty. Videolaryngoscopy, on the other hand, rarely fails to provide adequate laryngeal visualization, so characterization of difficult videolaryngoscopy predictors may not be possible. Like DL, adequate video views are highly correlated with intubation success, although the strength of this association can depend on the device used and operator experience.[3,6,7] Whether DL or videolaryngoscopy is planned, a standard screening process for difficulty should be undertaken with every patient. Our recommended approach uses the mnemonic *LEMON* (Box 1.1).

***L*—Look Externally.** The patient first should be examined for external markers of difficult intubation, which are determined

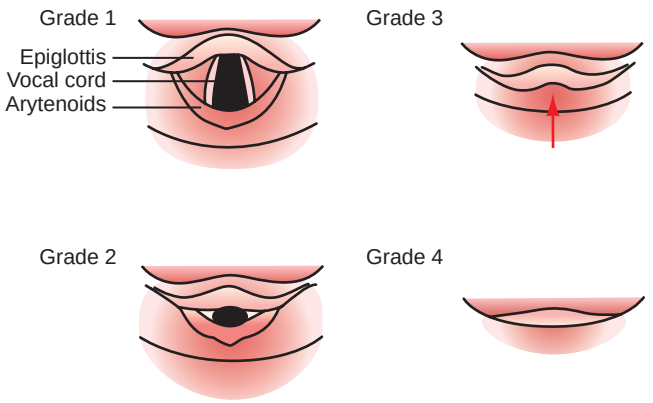

Fig. 1.1. Cormack and Lehane grading system for glottic view. (Modified from Walls RM, Murphy MF, editors: Manual of emergency airway management, ed 4, Philadelphia, 2012, Lippincott, Williams & Wilkins; with permission.)

BOX 1.1

LEMON Mnemonic for Evaluation of Difficult Direct Laryngoscopy

Look externally for signs of difficult intubation (by gestalt)
Evaluate 3-3-2 rule
Mallampati scale
Obstruction or *o*besity
Neck mobility

Adapted with permission from The Difficult Airway Course: Emergency and Walls RM, Murphy MF, eds: Manual of Emergency Airway Management, 4th ed. Philadelphia: Lippincott, Williams & Wilkins; 2012.

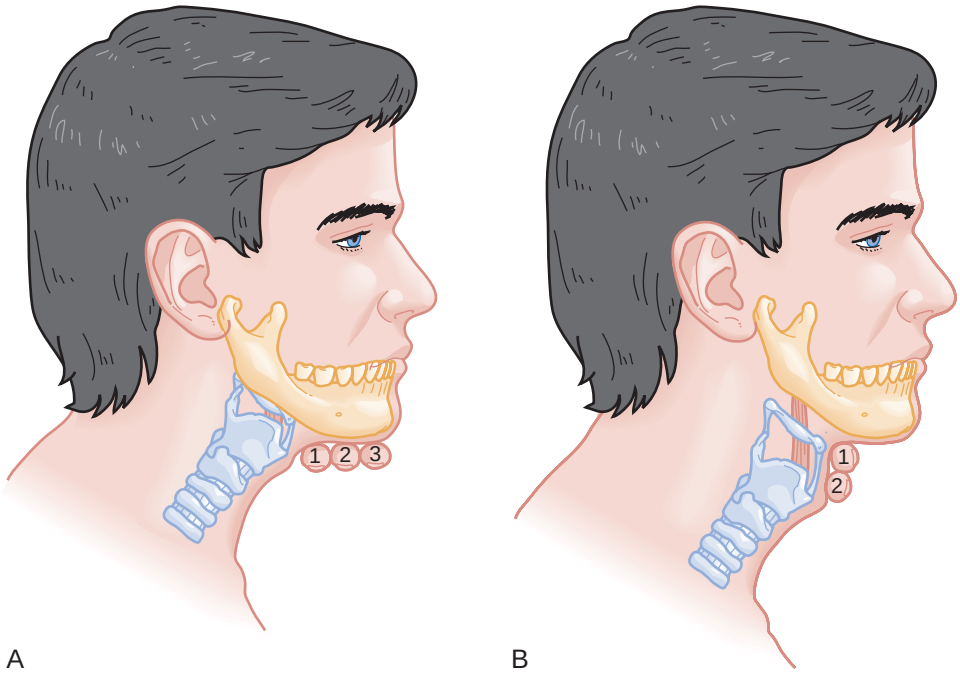

Fig. 1.2. Final two steps of the 3-3-2 rule. A, Three fingers are placed along the floor of the mouth, beginning at the mentum. B, Two fingers are placed in the laryngeal prominence (Adam's apple). (Modified from Murphy MF, Walls RM: Identification of difficult and failed airways. In Walls RM, Murphy MF, editors: Manual of emergency airway management, ed 4, Philadelphia, 2012, Lippincott, Williams & Wilkins; the 3-3-2 rule copyright © 2012 by The difficult airway course: emergency; and Lippincott Williams & Wilkins, publishers, Manual of emergency airway management.)

based simply on the intubator's clinical impression or initial gestalt. For example, the severely bruised and bloodied face of a combative trauma patient, immobilized in a cervical collar on a spine board, should (correctly) invoke an immediate appreciation of anticipated difficult intubation. Subjective clinical judgment can be highly specific but insensitive and so should be augmented by other evaluations whether or not the airway appears to be challenging.

***E*—Evaluate 3-3-2.** The second step in the evaluation of the difficult airway is to assess the patient's airway geometry to determine suitability for DL. Glottic visualization with a direct laryngoscope necessitates that the mouth opens adequately, the submandibular space is adequate to accommodate the tongue, and the larynx be positioned low enough in the neck to be accessible. These relationships have been explored in various studies by external measurements of mouth opening, oropharyngeal size, neck movement, and thyromental distance. The 3-3-2 rule is an effective summary of these assessments.[8] The 3-3-2 rule requires that the patient be able to place three of his or her own fingers between the open incisors, three of his or her own fingers along the floor of the mandible beginning at the mentum, and two fingers from the laryngeal prominence to the underside of the chin (Fig. 1.2). A patient with a receding mandible and high-riding larynx is impossible to intubate using DL because the operator cannot adequately displace the tongue and overcome the acute angle for a direct view of the glottic aperture In practice, the operator compares the size of his or her fingers with the size of the patient's fingers and then performs the three tests.

***M*—Mallampati Scale.** Oral access is assessed with the Mallampati scale (Fig. 1.3). Visibility of the oral pharynx ranges from complete visualization, including the tonsillar pillars (class I), to no visualization at all, with the tongue pressed against the hard palate (class IV). Classes I and II predict adequate oral access, class

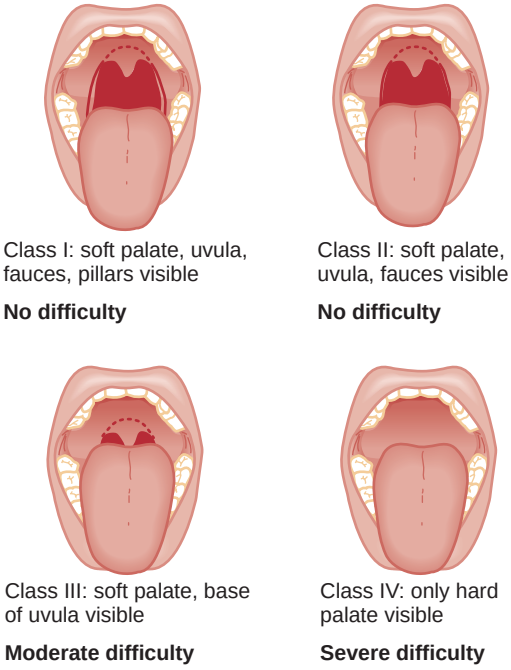

Fig. 1.3. The Mallampati scale, classes I to IV, assesses oral access for intubation. (From Whitten CE: Anyone can intubate, ed 4, San Diego, CA, 2004; with permission.)

III predicts moderate difficulty, and class IV predicts a high degree of difficulty. A meta-analysis has confirmed that the four-class Mallampati score performs well as a predictor of difficult laryngoscopy (and, less so, of difficult intubation), but the Mallampati score alone is not a sufficient assessment tool. A Mallampati score necessitates an awake compliant patient to perform the assessment in the way in which it was originally described. Nearly 50%

of ED patients cannot willingly perform this assessment, but it can be improvised by using a direct laryngoscope blade as a tongue depressor in obtunded or uncooperative patients.[9]

***O*—Obstruction or Obesity.** Upper airway (supraglottic) obstruction may make visualization of the glottis, or intubation itself, mechanically impossible. Conditions such as epiglottitis, head and neck cancer, Ludwig's angina, neck hematoma, glottis swelling, or glottic polyps can compromise laryngoscopy, passage of the endotracheal tube (ETT), BMV, or all three. Examine the patient for airway obstruction and assess the patient's voice to satisfy this evaluation step. Although obesity alone may not be an independent marker of difficult direct laryngoscopy, it likely contributes to challenges in other areas of airway management. Nevertheless, obese patients generally are more difficult to intubate than their nonobese counterparts, and preparations should account for this and for the more rapid oxyhemoglobin desaturation and increased difficulty with ventilation using BMV or an EGD (see later).

***N*—Neck Mobility.** Neck mobility is desirable for any intubation technique and is essential for positioning the patient for optimal DL. Neck mobility is assessed by flexion and extension of the patient's head and neck through a full range of motion. Neck extension is the most important motion, but placing the patient in the full sniffing position provides the optimal laryngeal view by DL.[10] Modest limitations of motion do not seriously impair DL, but severe loss of motion, as can occur in ankylosing spondylitis or rheumatoid arthritis, for example, may make DL impossible. Cervical spine immobilization in trauma patients artificially reduces cervical spine mobility, but DL is still highly successful in this group of patients.[7]

A similar mnemonic, *LEMONS*, has been described, with the "S" referring to the patient's oxygen saturation. Although not a direct contributor to difficulty with DL, a low starting oxygen saturation will result in a shorter period of safe apnea and a truncated time to perform laryngoscopy and successful endotracheal tube placement. As noted, identification of a difficult intubation does not preclude use of an RSI technique. The crucial determination is whether the emergency clinician judges that the patient has a reasonable likelihood of intubation success, despite the difficulties identified, and that ventilation with BMV or an EGD will be successful in case intubation fails (hence, the value of the BMV and EGD assessments; see Boxes 1.2 and 1.3).

Difficult Bag-Mask Ventilation: MOANS

Attributes of difficult BMV have largely been validated and can be summarized with the mnemonic *MOANS* (Box 1.2).

- ***M***ask seal compromise or difficulty
- ***O***bstruction (particularly supraglottic obstruction, but can be present anywhere in the airway) or ***O***besity (because of redundant upper airway tissues, chest wall weight, and resistance of abdominal mass)
- Advanced ***A***ge (best judged by the physiologic appearance of the patient, but age older than 55 years increases risk)
- Edentulous patients ("***N***o teeth"), which independently interferes with mask seal
- ***S***tiffness or resistance to ventilation (eg, asthma, COPD, pulmonary edema, restrictive lung disease, term pregnancy)—may contribute to increased difficulty with BMV

The difficulty with BMV of the edentulous patient is the basis of the advice often cited for patients with dentures: "teeth out to intubate, teeth in to ventilate." Another approach involves placing the mask inside the patient's lower lip. This may limit air leak in patients without teeth and eliminates the risk of aspiration associated with dental prosthetics or rolled gauze (Fig. 1.4).[11] Difficult BMV is not uncommon but, with proper technique, it usually is successful. A review by Kheterpal et al of more than 50,000 patients undergoing elective anesthesia has found that impossible BMV is exceptionally rare (0.2%) and is associated with neck changes secondary to radiation therapy, presence of a beard, male gender, history of sleep apnea, and Mallampati class III or IV airway.[11a] Impossible BMV was five times more likely if one of these factors was present and 25 times more likely with four or more.

Difficult Extraglottic Device Placement: RODS

Placement of an EGD, such as a laryngeal mask airway (LMA), Combitube, or similar upper airway device, often can convert a can't intubate, can't oxygenate situation to a can't intubate, can oxygenate situation, which allows time for rescue of a failed airway (see following section). Difficulty achieving placement or ventilation with an EGD can be predicted by the mnemonic *RODS*. Fortunately, if the emergency clinician has already performed the LEMON and MOANS assessments, only the *D* for distorted anatomy remains to be evaluated (Box 1.3). EGDs are placed blindly and have a mask or balloon structure that, when inflated, obstructs the oropharynx proximally and esophageal inlet distally, permitting indirect ventilation. Distorted upper airway anatomy can result in a poor seal and ineffective ventilation.

Difficult Cricothyrotomy: SMART

Difficult cricothyrotomy can be anticipated whenever there is limited access to the anterior neck or obscured laryngeal

BOX 1.2

MOANS Mnemonic for Evaluation of Difficult Bag-Mask Ventilation

Mask seal
Obstruction or obesity
Aged
No teeth
Stiffness (resistance to ventilation)

Adapted with permission from The Difficult Airway Course: Emergency and Walls RM, Murphy MF, eds: Manual of Emergency Airway Management, 4th ed. Philadelphia: Lippincott, Williams & Wilkins; 2012.

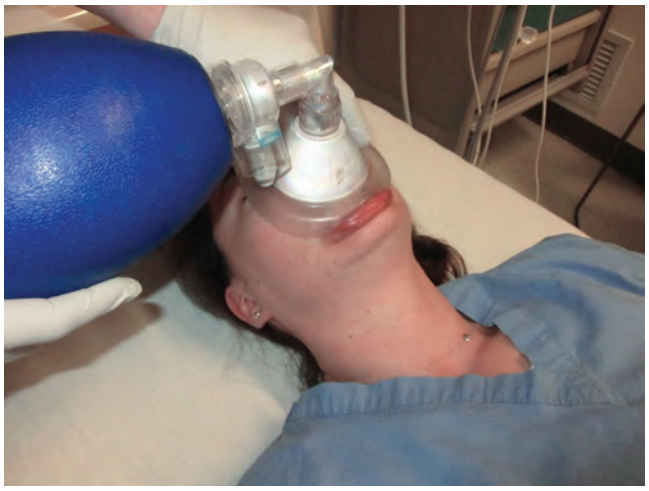

Fig. 1.4. Mask ventilation in edentulous patients can be performed by placing the lower rim of the mask on the inside of the patient's lower lip to improve mask seal. (Courtesy Dr. Tobias Barker.)

BOX 1.3

RODS Mnemonic for Evaluation of Difficult Extraglottic Device Placement

Restricted mouth opening
Obstruction or obesity
Distorted anatomy
Stiffness (resistance to ventilation)

Adapted with permission from The Difficult Airway Course: Emergency and Walls RM, Murphy MF, eds: Manual of Emergency Airway Management, 4th ed. Philadelphia: Lippincott, Williams & Wilkins; 2012.

BOX 1.4

SMART Mnemonic for Evaluation of Difficult Cricothyrotomy

Surgery
Mass (abscess, hematoma)
Access/anatomy problems (obesity, edema)
Radiation
Tumor

Adapted with permission from The Difficult Airway Course: Emergency and Walls RM, Murphy MF, eds: Manual of Emergency Airway Management, 4th ed. Philadelphia: Lippincott, Williams & Wilkins; 2012.

landmarks and can be remembered by the mnemonic *SMART* (Box 1.4). Prior surgery, hematoma, tumor, abscess, scarring (as from radiation therapy or prior injury), local trauma, obesity, edema, or subcutaneous air each has the potential to make cricothyrotomy more difficult. Perform an examination for the landmarks needed to perform cricothyrotomy as part of the preintubation difficult airway assessment of the patient. Point-of-care ultrasound has been used at the bedside to locate the cricothyroid membrane, thereby allowing the emergency clinician to mark the location on the surface of the neck in high-risk cases. The emergency clinician should not avoid performing a rescue cricothyrotomy when indicated, even in the presence of predicted difficulty.

Measurement and Incidence of Intubation Difficulty

The actual degree to which an intubation is difficult is highly subjective, and quantification is challenging. The CL system is the most widely used system for grading a laryngoscopic view of the glottis, which grades laryngoscopy according to the extent to which laryngeal and glottic structures can be seen (see Fig. 1.1). In grade 1 laryngoscopy, all or nearly all of the glottic aperture is seen; in grade 2, the laryngoscopist visualizes only a portion of the glottis (arytenoid cartilages alone or arytenoid cartilages plus part of the vocal cords), in grade 3 only the epiglottis is visualized and, in grade 4, not even the epiglottis is visible.

Fewer than 1% of stable patients undergoing DL during elective anesthesia yield a grade 4 laryngoscopy, a finding associated with an extremely difficult intubation with. Grade 3 laryngoscopy, which represents highly difficult intubation, is found in less than 5% of patients. Grade 2 laryngoscopy, which occurs in 10% to 30% of patients, can be subdivided further into grade 2a, in which the arytenoids and a portion of the vocal cords are seen, and grade 2b, in which only the arytenoids are seen. Intubation failure occurs in 67% of grade 2b cases but in only 4% of grade 2a cases.

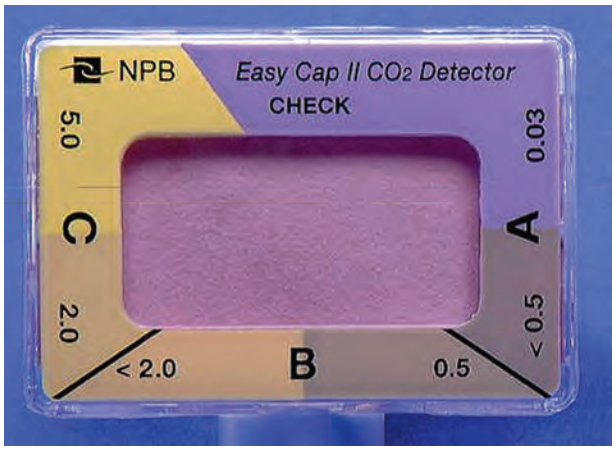

Fig. 1.5. End-tidal CO_2 detector before application. The indicator is *purple*, which indicates failure to detect CO_2. This also is the appearance when the esophagus is intubated.

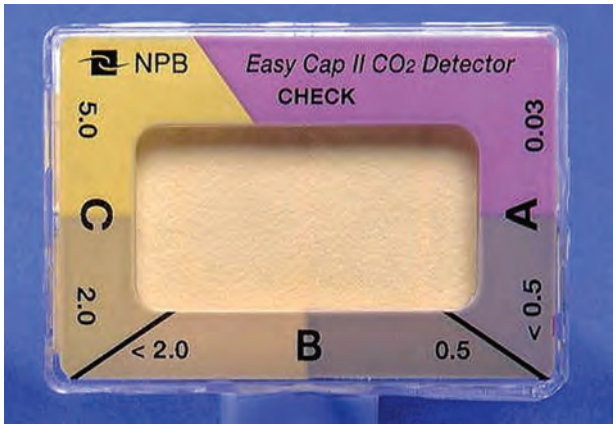

Fig. 1.6. Positive detection of CO_2 turns the indicator *yellow*, indicating tracheal placement of the endotracheal tube.

Outside of the operating room, the rate of difficulty may be higher. In a recent review of emergency adult inpatient intubations, as many as 10% were considered difficult (grade 3 or 4 CL direct view or more than three attempts required).[12] The incidence of difficult ED intubations is unknown but is likely much higher Approximately 80% of all grade 2 laryngoscopies are grade 2a; the rest are grade 2b. First-attempt intubation success drops off significantly as the glottic view transitions from a grade 2a to 2b; however, a grade 1 view is associated with virtually 100% intubation success. An alternative system, POGO (percentage of glottic opening), also has been proposed and validated but has not been widely used or studied. The incidence of difficult intubation, and the predictors thereof, are largely based on the use of conventional DL and are not applicable to videolaryngoscopy.

Confirmation of Endotracheal Tube Placement

Immediately after intubation, the intubator should apply an end-tidal carbon dioxide ($ETCO_2$) detection device to the ETT and assess it through six manual ventilations. Disposable colorimetric $ETCO_2$ detectors are highly reliable, convenient, and easy to interpret, indicating adequate CO_2 detection by color change (Figs. 1.5 and 1.6) and determining tracheal and esophageal intubation in patients with spontaneous circulation. The persistence of detected CO_2 after six manual breaths indicates that the tube is within the airway, although not necessarily within the trachea. CO_2 is detected with the tube in the mainstem bronchus, trachea, or supraglottic

space. Correlation of $ETCO_2$ detection with the depth markings on the ETT, particularly important in pediatric patients, confirms tracheal placement. Rarely, BMV before intubation or ingestion of carbonated beverages may lead to the release of CO_2 from the stomach after esophageal intubation, causing a transient false indication of tracheal intubation. Washout of this phenomenon universally occurs within six breaths.

Although colorimetric $ETCO_2$ measurement is highly sensitive and specific for detecting esophageal intubation, caution is required for patients in cardiopulmonary arrest. Insufficient gas exchange may prevent CO_2 detection in the exhaled air, even when the tube is correctly placed within the trachea. In patients in cardiopulmonary arrest, a CO_2 level greater than 2%, which is the threshold for color change on colorimetric capnometers, should be considered definitive evidence of correct ETT placement, but the absence of such CO_2 cannot be used reliably as an indicator of esophageal intubation. Recent resuscitation guidelines have suggested continuous quantitative measurement of $ETCO_2$ during cardiac arrest to gauge the efficacy of cardiopulmonary resuscitation.[13] This circumstance arises in approximately 25% to 40% of intubated cardiac arrest patients. In all other patients, absence of CO_2 detection indicates failure to intubate the trachea, and rapid reintubation is indicated.

When $ETCO_2$ detection is not possible, tracheal tube position can be confirmed with other techniques. One approach involves point-of-care ultrasound. In live patient and cadaver studies, ultrasonography performed over the cricothyroid membrane or upper trachea has accurately confirmed ETT position in the trachea, especially during intubation.[14,15]

Another method of tube placement confirmation is the aspiration technique, based on the anatomic differences between the trachea and esophagus. The esophagus is a muscular structure with no support within its walls and is therefore collapsible when negative pressure is applied. The trachea is held patent by cartilaginous rings and thus is less likely to collapse when negative pressure is applied. Vigorous aspiration of air through the ETT with the ETT cuff deflated results in occlusion of the ETT orifices by the soft walls of the esophagus, whereas aspiration after tracheal placement of the tube is easy and rapid.

Bulb or syringe aspiration devices may be used in patients in cardiac arrest who have no detectable CO_2. Although such devices are highly reliable at detecting esophageal intubation (sensitivity > 95%), false-positives, in which a correctly placed tracheal tube is incorrectly identified as esophageal, can occur in up to 25% of cardiac arrest patients. Aspiration devices may be useful in the out-of-hospital setting when poor lighting hampers colorimetric $ETCO_2$ determination. They also are good backup devices when cardiac arrest confounds attempts to assess placement with $ETCO_2$. Detection of expired CO_2 is more reliable and is the standard for confirmation of tracheal placement of an ETT and for early detection of accidental esophageal intubation. Aspiration devices have a valuable but secondary role. Also, a bougie can be placed through the center of an ETT to corroborate tube location further. A bougie that can be passed deeply through the tube, with little or no resistance, suggests an esophageal intubation because the bougie has likely passed beyond the tube and into the stomach. If the ETT is in the trachea, the tip of the bougie will become wedged after only a few inches, likely in the right mainstem bronchus, and a vibration from contact with the anterior tracheal rings may be transmitted to the operator's fingertips.

Accordingly, $ETCO_2$ detection, with aspiration, bougie, or an ultrasound technique as backup, should be considered the primary means of ETT placement confirmation. Secondary means include physical examination findings, oximetry, and radiography. The examiner should auscultate both lung fields and the epigastric area. Pulse oximetry is indicated as a monitoring technique in all critically ill patients, not just those who require intubation. Oximetry is useful in detecting esophageal intubation but may not show a decreasing oxygen saturation for several minutes after a failed intubation because of the oxygen reservoir (preoxygenation) created in the patient before intubation. Although chest radiography is universally recommended after ETT placement, its primary purpose is to ensure that the tube is well positioned below the cords and above the carina. A single anteroposterior chest radiograph is not sufficient to detect esophageal intubation, although esophageal intubation may be detected if the ETT is clearly outside the air shadow of the trachea. In cases in which doubt persists, a fiberoptic scope can be passed through the ETT to identify tracheal rings, another gold standard for confirmation of tracheal placement.

MANAGEMENT

Decision Making

Algorithms for emergency airway management have been developed and provide a useful guide for planning intubation and rescue in case of intubation failure. The algorithm assumes that a decision to intubate has been made and outlines such an approach. The approach is predicated on two key determinations that are to be made before active airway management is initiated (Fig. 1.7). The first determination is whether the patient is in cardiopulmonary arrest or a state of near arrest and is likely to be unresponsive to direct laryngoscopy. Such a patient—agonal, near death, in

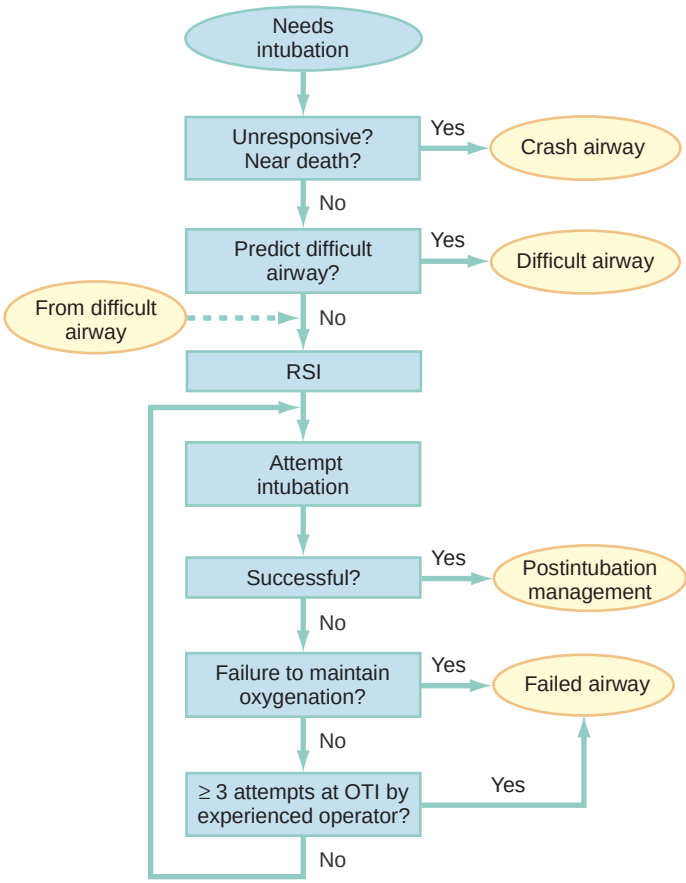

Fig. 1.7. Main emergency airway management algorithm. *OTI,* Orotracheal intubation; *RSI,* rapid sequence intubation. (Modified from Walls RM: The emergency airway algorithms. In Walls RM, Murphy MF, editors: Manual of emergency airway management, ed 4, Philadelphia, 2012, Lippincott, Williams & Wilkins; copyright © 2012, The difficult airway course: emergency; and Lippincott, Williams & Wilkins, publishers.)

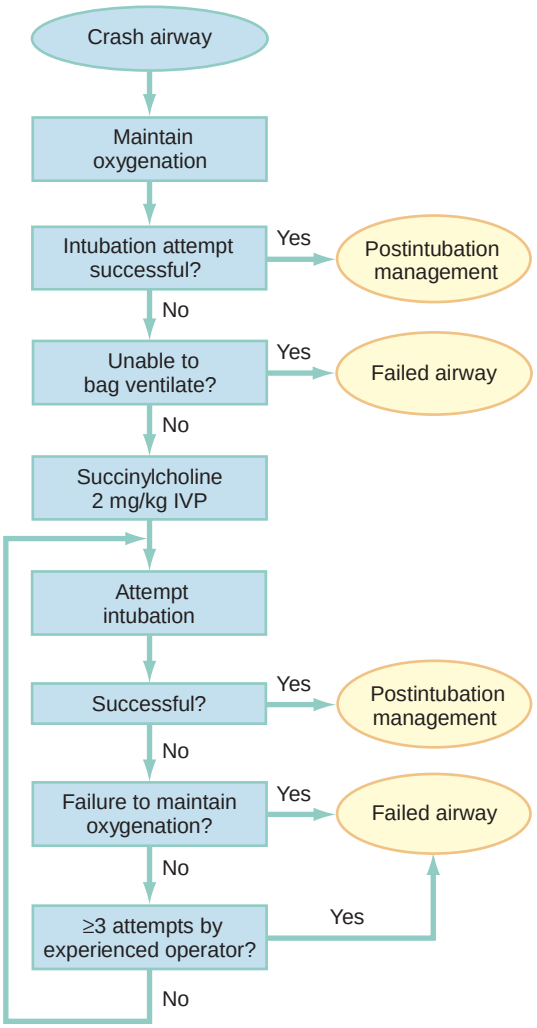

Fig. 1.8. Crash airway algorithm. *IVP,* Intravenous push. (Modified from Walls RM: The emergency airway algorithms. In Walls RM, Murphy MF, editors: Manual of emergency airway management, ed 4, Philadelphia, 2012, Lippincott, Williams & Wilkins; copyright © 2012, The difficult airway course: emergency; and Lippincott, Williams & Wilkins, publishers.)

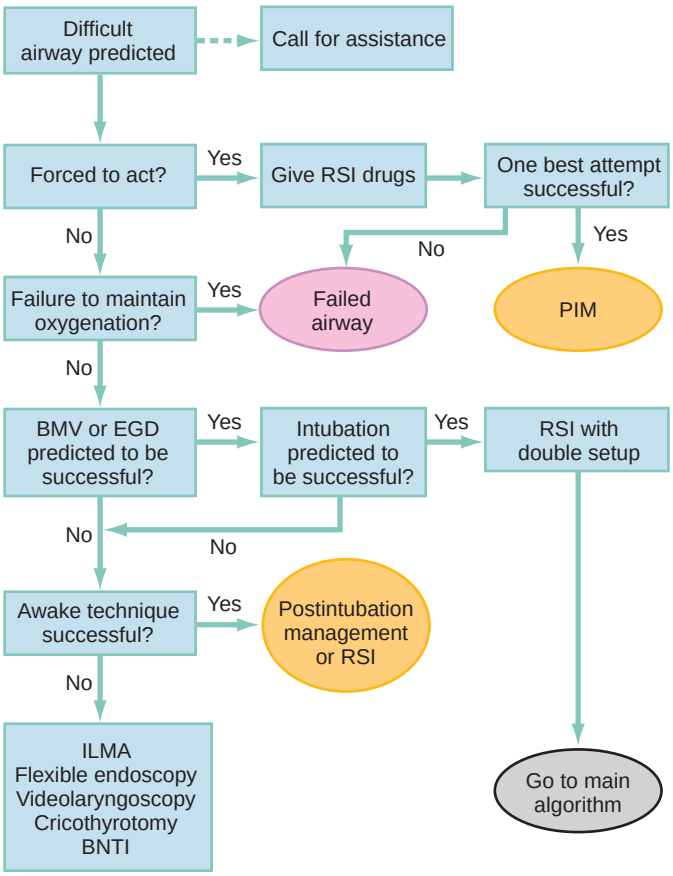

Fig. 1.9. Difficult airway algorithm. *BMV,* Bag-mask ventilation; *BNTI,* blind nasotracheal intubation; *DL,* direct laryngoscopy; *EGD,* extraglottic device; *ILMA,* intubating laryngeal mask airway; *PIM,* postintubation management; *RSI,* rapid sequence intubation. (Modified from Walls RM: The emergency airway algorithms. In Walls RM, Murphy MF, editors: Manual of emergency airway management, ed 4, Philadelphia, 2012, Lippincott, Williams & Wilkins; copyright © 2012, The difficult airway course: emergency; and Lippincott, Williams & Wilkins, publishers.)

circulatory collapse—is deemed a crash airway patient for the purposes of emergency airway management and is treated using the crash airway algorithm by an immediate intubation attempt without use of drugs; this can be supplemented by a single large dose of succinylcholine if the attempt to intubate fails, and the patient is thought not to be sufficiently relaxed (Fig. 1.8). If a crash airway is not present, a decision of whether the patient represents a difficult intubation, as determined by the LEMON, MOANS, RODS, and SMART evaluations is made and, if so, the difficult airway algorithm is used (Fig. 1.9).

For patients who require emergency intubation but who have neither a crash airway nor a difficult airway, RSI is indicated. RSI provides the safest and quickest method of achieving intubation in such patients.[3,16] After administration of RSI drugs, intubation attempts are repeated until the patient is intubated or a failed intubation is identified. If more than one intubation attempt is required, oxygen saturation is monitored continuously and, if saturation falls to 90% or less, BMV is performed until saturation is recovered for another attempt. If the oxygen saturation continues to fall, despite optimal use of BMV or EGD, a failed airway exists. This is referred to as a can't intubate, can't oxygenate scenario. A failed airway also is defined as three unsuccessful attempts at laryngoscopy because subsequent attempts at laryngoscopy by the same clinician are unlikely to succeed. The three failed laryngoscopy attempts are defined as attempts by an experienced clinician using the best possible patient positioning and technique. Three attempts by a physician trainee using a direct laryngoscope may not count, necessarily, as best attempts if an experienced emergency clinician is available or videolaryngoscopy has not yet been attempted. Also, if the emergency clinician ascertains after even a single attempt that intubation will be impossible (eg, grade 4 laryngoscopic view with DL, despite optimal patient positioning and use of external laryngeal manipulation), and no alternative device (eg, videolaryngoscope, intubating LMA) is available, a failed airway is present. The failed airway is managed according to the failed airway algorithm (Fig. 1.10).

Difficult Airway

The perception of a difficult airway is relative, and many emergency intubations could be considered difficult. Deciding whether to treat the airway as a typical emergency airway or whether to use the difficult airway algorithm is based on the degree of perceived difficulty, operator experience, armamentarium of airway devices available, and individual circumstances of the case. The LEMON, MOANS, RODS, and SMART assessments provide a systematic framework to assist in identifying the potentially difficult airway.

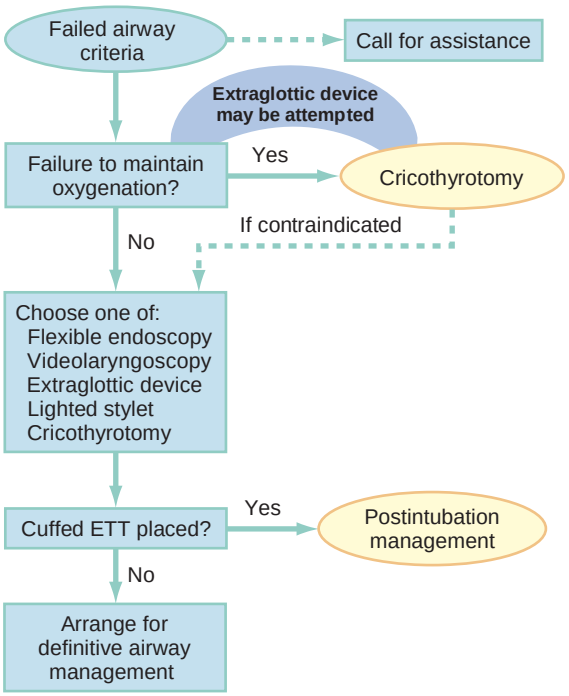

Fig. 1.10. Failed airway algorithm. *ETT,* Endotracheal tube. (Modified from Walls RM: The emergency airway algorithms. In Walls RM, Murphy MF, editors: Manual of emergency airway management, ed 4, Philadelphia, 2012, Lippincott, Williams & Wilkins; copyright © 2012, The difficult airway course: emergency; and Lippincott, Williams & Wilkins, publishers.)

When preintubation evaluation identifies a potentially difficult airway (see Fig. 1.9), the approach is based on the premise that NMBAs generally should not be used unless the emergency clinician believes that (1) intubation is likely to be successful and (2) oxygenation can be maintained via BMV or EGD should the patient desaturate during a failed intubation attempt. The one exception to this recommendation occurs in the forced to act scenario.

A forced to act imperative permits RSI, even in a highly difficult airway situation in which the operator is not confident of the success of laryngoscopy or of sustaining oxygenation. This usually occurs in the setting of a rapidly deteriorating patient with an obviously difficult airway and a presumed clinical trajectory of imminent arrest. Although this is not yet a crash airway situation, the operator is forced to act—that is, there is a need to act immediately to intubate before orotracheal intubation quickly becomes impossible or the patient arrests. The patient retains sufficient muscle tone and voluntary effort (including combative behavior induced by hypoxia) to require administration of drugs before intubation can be attempted. Consider an agitated patient with rapidly advancing anaphylaxis or angioedema, a morbidly obese patient in severe, end-stage status asthmaticus, or an intensive care unit (ICU) patient with inadvertent or premature extubation, respiratory failure, and difficult airway. Within seconds to minutes, perhaps before a full difficult airway assessment can be done or preparations can be completed for an alternative airway approach (eg, flexible endoscopy), the patient's rapid deterioration signals impending respiratory arrest. This is a unique situation in which the operator may be compelled to take the one best chance to secure the airway by rapidly administering RSI drugs, despite obvious airway difficulty, and attempting intubation before the airway crisis has advanced to the point that intubation is impossible or delay has caused hypoxic arrest. If laryngoscopy fails, the RSI drugs have optimized patient conditions for cricothyrotomy or insertion of an alternative airway device, depending on the operator's judgment.

Therefore, in the difficult airway algorithm, the first determination is whether the operator is forced to act. If so, RSI drugs are given, a best attempt at laryngoscopy is undertaken and, if intubation is not successful, the airway is considered failed, and the operator moves immediately to the failed airway algorithm. In the vast majority of difficult airway situations, however, the operator is not forced to act, and the first step is to ensure that oxygenation is sufficient to permit a planned orderly approach to airway management. If oxygenation is inadequate and cannot be made adequate by supplementation with BMV, the airway should be considered a failed airway. Although inadequate oxygenation should be defined on a case by case basis, oxygenation saturation falling below 90% is the accepted threshold, because this represents the point at which hemoglobin undergoes a conformational change, more readily releases oxygen, and increases the pace of further desaturation. Oxyhemoglobin saturations in the mid-80s, if holding steady, might be considered adequate in some circumstances, particularly if the patient is chronically hypoxemic. When oxygenation is inadequate or dropping, the failed airway algorithm should be used because the predicted high degree of intubation difficulty, combined with failure to maintain oxygen saturation, is analogous to the can't intubate, can't oxygenate scenario.

When oxygenation is adequate, however, the next consideration is whether RSI is appropriate, on the basis of the operator's assessment of the likelihood of (1) successful ventilation with BMV or EGD in case intubation is unsuccessful and (2) the likelihood of successful intubation by laryngoscopy. If the operator judges laryngoscopy likely to succeed and is confident that he or she can oxygenate the patient if intubation fails, RSI is performed. In such cases, a double setup can be used in which RSI is planned and preparations are simultaneously undertaken for rescue cricothyrotomy or another rescue technique. If the operator is not confident of successful intubation by RSI and time allows, an awake technique can be used. In this context, awake means that the patient continues to breathe and, although intravenous sedation and analgesia may be administered, can cooperate with caregivers. The patient is prepared by applying topical anesthesia with atomized or nebulized lidocaine, ideally preceded by a drying agent such as glycopyrrolate. Titrated doses of a sedative and analgesic agents (or ketamine, which provides both actions) may be required for the patient to tolerate the procedure. Once this is accomplished, a number of different devices can then be used to attempt glottic visualization, although flexible bronchoscopes and videolaryngoscopes are preferable. If the glottis is adequately visualized, the patient can be intubated at that time or, in a stable difficult airway situation, the emergency clinician may proceed with planned RSI, now assured of intubation success. If the awake laryngoscopy is unsuccessful, the patient can be intubated with any of numerous techniques shown in the last box in Fig. 1.9. For each of these methods, the patient is kept breathing but is variably sedated and anesthetized. The choice among these methods depends on clinician experience and preference, device availability, and patient attributes.

Failed Airway

Management of the failed airway is dictated by whether the patient can be oxygenated. If adequate oxygenation cannot be maintained with rescue BMV, the rescue technique of first resort is cricothyrotomy (see Fig. 1.10). Multiple attempts at other methods in the context of failed oxygenation only delay cricothyrotomy and place the patient at increased risk for hypoxic brain injury. If an alternative device (ie, an EGD such as an LMA or Combitube) is readily available, however, and the operator judges it to be an appropriate device for the patient's anatomy, single attempt can

be made to use it simultaneously with preparations for immediate cricothyrotomy as long as initiation of cricothyrotomy is not delayed. If early indications are that an EGD is effective and oxygenation improves, cricothyrotomy can wait; however, the operator must constantly reassess EGD function and oxygenation status. If the EGD subsequently fails, cricothyrotomy must begin without delay.

If adequate oxygenation is possible, several options are available for the failed airway. In almost all cases, cricothyrotomy is the definitive rescue technique for the failed airway if time does not allow for other approaches (ie, preservation of oxygenation) or if they fail. The fundamental difference in philosophy between the difficult and failed airway is that the difficult airway is planned for, and the standard is to place a definitive airway (cuffed ETT) in the trachea. The failed airway is not planned for, and the standard is to achieve an airway that provides adequate oxygenation to avert hypoxic brain injury. Some devices used in the failed airway (eg, EGDs) are temporary and do not provide definitive airway protection.

Methods of Intubation

Although many techniques are available for intubation of the emergency patient, four methods are the most common, with RSI being the most frequent approach.[3,16]

Rapid Sequence Intubation

RSI is the cornerstone of modern emergency airway management and is defined as the nearly simultaneous administration of a potent sedative (induction) agent and NMBA, usually succinylcholine or rocuronium, for the purpose of tracheal intubation. This approach provides optimal intubating conditions and has long been thought to minimize the risk of aspiration of gastric contents. A systematic review of the literature in 2007 failed to prove that RSI results in a lower incidence of aspiration than other techniques, but the authors correctly noted that virtually no studies have ever been designed to measure this precise endpoint. RSI is nevertheless the most widely used technique for emergency intubation of patients without identifiable difficult airway attributes, with recent large registry data showing that it is used in 85% of all emergency department intubations.[3,16]

The central concept of RSI is to take the patient from the starting point (eg, conscious, breathing spontaneously) to a state of unconsciousness with complete neuromuscular paralysis, and then to achieve intubation without interposed assisted ventilation. The risk of aspiration of gastric contents is thought to be significantly higher for patients who have not fasted before induction. Application of positive-pressure ventilation can cause air to pass into the stomach, resulting in gastric distention and likely increasing the risk of regurgitation and aspiration. The purpose of RSI is to avoid positive-pressure ventilation until the ETT is placed correctly in the trachea, with the cuff inflated. This requires a preoxygenation phase, during which mixed alveolar gases (mostly nitrogen) within the lungs' functional residual capacity are replaced with oxygen, permitting at least several minutes of apnea (see later discussion) in a healthy normal body habitus adult before oxygen desaturation to less than 90% ensues (Fig. 1.11).

Use of RSI also facilitates successful endotracheal intubation by causing complete relaxation of the patient's musculature, allowing better access to the airway. Finally, RSI permits pharmacologic control of the physiologic responses to laryngoscopy and intubation, mitigating potential adverse effects. These effects include further elevations in intracranial pressure (ICP) in response to the procedure and to the sympathetic discharge resulting from laryngoscopy (Box 1.5). RSI is a series of discrete steps, and every step should be planned (Box 1.6).

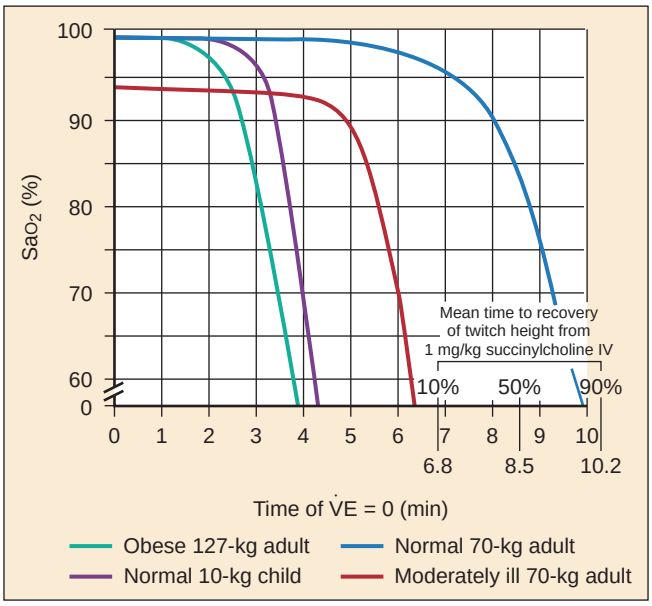

Fig. 1.11. Desaturation time for apneic, fully preoxygenated patients. Children, patients with comorbidity, and obese patients desaturate much more rapidly than healthy normal adults. The box on the lower right side of the graph depicts time to recovery from succinylcholine, which in almost all cases exceeds safe apnea time. Note also the precipitous decline of oxygen saturation from 90% to 0% for all groups. *VE,* Expired volume. (Modified from Benumof JL, Dagg R, Benumof R: Critical hemoglobin desaturation will occur before return to unparalyzed state following 1 mg/kg intravenous succinylcholine. Anesthesiology 87:979–982, 1997.)

BOX 1.5

Pretreatment Agents for Rapid Sequence Intubation[a]

Reactive airway disease: Albuterol, 2.5 mg, by nebulizer. If time does not permit albuterol nebulizer, give lidocaine 1.5 mg/kg IV.
Cardiovascular disease: Fentanyl, 3 µg/kg, to mitigate sympathetic discharge
Elevated ICP: Fentanyl, 3 µg/kg, to mitigate sympathetic discharge and attendant rise in ICP

ICP, intracranial pressure.
[a]Given 2–3 min before induction and paralysis.

BOX 1.6

The Seven Ps of Rapid Sequence Intubation

1. ***P****reparation*
2. ***P****reoxygenation*
3. ***P****retreatment*
4. ***P****aralysis with induction*
5. ***P****ositioning*
6. ***P****lacement of tube*
7. ***P****ostintubation management*

Preparation. In the initial phase, the patient is assessed for intubation difficulty, unless this has already been done, and the intubation is planned, including determining dosages and sequence of drugs, tube size, and laryngoscope type, blade, and size. Drugs are drawn up and labeled. All necessary equipment is

assembled. All patients require continuous cardiac and pulse oximetry monitoring. At least one and preferably two good-quality intravenous lines should be established. Redundancy is always desirable in case of equipment or intravenous access failure. Most importantly, a rescue plan for intubation failure should be developed at this time and made known to the appropriate members of the resuscitation team.

Preoxygenation. Administration of 100% oxygen for 3 minutes of normal tidal volume breathing in a normal healthy adult establishes an adequate oxygen reservoir to permit 6 to 8 minutes of safe apnea before oxygen desaturation to less than 90% occurs (see Fig. 1.11). Additional preoxygenation does not improve arterial oxygen tension. The time to desaturation to less than 90% in children, obese adults, late-term pregnant women, and patients who are acutely ill or injured is considerably shorter. Desaturation time also is reduced if the patient does not inspire 100% oxygen. Nevertheless, adequate preoxygenation usually can be obtained, even in ED patients, to permit minutes of apnea before there is oxygen desaturation to less than 90%. Preoxygenation is also essential to the no-bagging approach of RSI. If time is insufficient for a full 3-minute preoxygenation phase, eight vital capacity breaths with high-flow oxygen can achieve oxygen saturations and apnea times that match or exceed those obtained with traditional preoxygenation. Desaturation time in obese patients can be prolonged by preoxygenating with the patient in a head-up position and by continuing supplemental oxygen (via nasal cannula at a flow rate of 5–15 L/min) after motor paralysis and during laryngoscopy until the ETT is successfully placed. In obese patients, it extends the time to desaturation to 95% from 3.5 to 5.3 minutes.[17,18] This so-called apneic oxygenation takes advantage of a physiologic principle termed *aventilatory mass flow*.[19] Even though patients are paralyzed during RSI, circulation is unaltered. The constant diffusion of alveolar oxygen into the pulmonary circulation creates a natural downward gradient promoting passive oxygen movement from the patient's upper airway into the gas-exchanging portions of the lungs. Oxygen saturation monitors permit earlier detection of desaturation during laryngoscopy, but preoxygenation remains an essential step in RSI.

Pretreatment. During this phase, drugs are administered 3 minutes before the administration of succinylcholine and an induction agent to mitigate the adverse physiologic effects of laryngoscopy and intubation on the patient's presenting condition. Pretreatment approaches have evolved over time. Periodic reappraisals of the available literature have whittled the pretreatment approach down to the bare essentials with a focus on optimizing patient physiology prior to any intubation attempts. Older practices, such as the routine use of atropine for intubation of small children, have largely been abandoned.

Intubation is intensely stimulating and results in a sympathetic discharge, or reflex sympathetic response to laryngoscopy (RSRL). In patients suffering from a hypertensive emergency, sympatholysis with fentanyl (3 mcg/kg IV) administered 3 minutes before RSI can optimize the patient's hemodynamics by attenuating spikes in blood pressure and shear forces, both of which are considered undesirable in patients with elevations of intracranial pressure (ICP), aortic disease, acute coronary syndromes and neurovascular emergencies.

Patients with reactive airways disease can exhibit worsening pulmonary mechanics after intubation as a result of bronchospasm. Controversy exists regarding whether lidocaine (1.5 mg/kg IV) confers any additional benefit, beyond albuterol, and should be considered optional at best. Asthmatic patients being intubated in the ED for status asthmaticus will have received albuterol before intubation, and it is unlikely in these patients that lidocaine has any additive protective effect and is not recommended. Lidocaine has a vanishing role in emergency airway management and may disappear completely in the near future (see Box 1.5).

Paralysis With Induction. In this phase, a potent sedative agent is administered by rapid intravenous (IV) push in a dose capable of producing unconsciousness rapidly. This is immediately followed by rapid administration of an intubating dose of an NMBA, either succinylcholine at a dose of 1.5 mg/kg IV or rocuronium, 1 mg/kg. It is usual to wait 45 seconds from when the succinylcholine is given and 60 seconds from when rocuronium is given to allow sufficient paralysis to occur. The results from two large meta-analyses have revealed that intubating conditions provided by each drug are equivalent as long as rocuronium is dosed between 1.0 and 1.2 mg/kg IV.

Positioning. The patient should be positioned for intubation as consciousness is lost. Usually, positioning involves head extension, often with flexion of the neck on the body. Although simple extension may be adequate, a full sniffing position with cervical spine extension and head elevation is optimal if DL is used.[10] The Sellick maneuver—application of firm, backward pressure over the cricoid cartilage with the goal of obstructing the cervical esophagus and reducing the risk of aspiration—had long been recommended to minimize the risk of passive regurgitation and hence aspiration, but is no longer recommended. The Sellick maneuver is incorrectly applied by a variety of operators, making laryngoscopy or intubation more difficult in some patients, and aspiration often occurs despite use of the Sellick maneuver. In many patients, the cervical esophagus is positioned lateral to the cricoid ring in a relationship that is exaggerated by posterior pressure, rarely resulting in esophageal obstruction. Accordingly, we do not recommend routine use of the Sellick maneuver, and it should be considered optional, applied selectively, and released or modified early if the laryngeal view is poor or tube passage is difficult. After administration of an induction agent and NMBA, although the patient becomes unconscious and apneic, BMV should not be initiated unless the oxygen saturation falls to 90%.

Placement of Tube. Approximately 45 to 60 seconds after administration of the NMBA, the patient is relaxed sufficiently to permit laryngoscopy. This is assessed most easily by moving the mandible to test for mobility and absence of muscle tone. Place the ETT during glottic visualization with the laryngoscope. Confirm placement, as described earlier. If the first attempt is unsuccessful but oxygen saturation remains high, it is not necessary to ventilate the patient with a bag and mask between intubation attempts. If the oxygen saturation is approaching 90%, the patient may be ventilated briefly with a bag and mask between attempts to reestablish the oxygen reservoir.

Postintubation Management. After confirmation of tube placement by $ETco_2$, obtain a chest radiograph to confirm that mainstem intubation has not occurred and to assess the lungs. If available, place the patient on continuous capnography. In general, long-acting NMBAs (eg, pancuronium, vecuronium) are avoided; the focus is on optimal management using opioid analgesics and sedative agents to facilitate mechanical ventilation. An adequate dose of a benzodiazepine (eg, midazolam, 0.1–0.2 mg/kg IV) and opioid analgesic (eg, fentanyl, 3–5 μg/kg IV, or morphine, 0.2–0.3 mg/kg IV) is given to improve patient comfort and decrease sympathetic response to the ETT. Propofol infusion (5–50 μg/kg/min IV) with supplemental analgesia is an effective method for managing intubated patients who do not have hypotension or ongoing bleeding and is especially helpful for management of neurologic emergencies because its clinical duration of action is very short (<5 minutes), allowing frequent neurologic examinations. An NMBA is added only if appropriate use of

TABLE 1.1

Sample Rapid Sequence Intubation Using Etomidate and Succinylcholine

TIME	STEP
Zero minus 10 min	Preparation
Zero minus 5 min	Preoxygenation—100% oxygen for 3 min or 8 vital capacity breaths
Zero minus 3 min	Pretreatment—as indicated
Zero	Paralysis with induction • Etomidate, 0.3 mg/kg • Succinylcholine, 1.5 mg/kg
Zero plus 30 s	Positioning—Sellick maneuver optional
Zero plus 45 s	Placement • Laryngoscopy and intubation • End-tidal carbon dioxide confirmation
Zero plus 2 min	Postintubation management • Sedation and analgesia as indicated • Initiate mechanical ventilation • NMBA only if needed after adequate sedation, analgesia

NMBA, Neuromuscular blocking agent.

sedation and analgesia fail to control the patient adequately or when ventilation is challenging because of by muscular activity. Table 1.1 presents a sample RSI protocol using etomidate and succinylcholine. Zero refers to the time at which the induction agent and succinylcholine are pushed.

Delayed Sequence Intubation

Delayed sequence intubation (DSI) is a new technique proposed to maximize preoxygenation in preparation for intubation.[20] Agitation, delirium, and confusion can make attempts at preoxygenation challenging, if not impossible, when a patient is unable to comply with conventional modes of supplemental oxygenation, such as a face mask or BL-PAP. DSI considers preoxygenation a procedure and uses dissociative doses of ketamine (1.0 mg/kg IV) as procedural sedation to accomplish this. A small, ED- and ICU-based multicenter observational study showed post-DSI oxygen saturations significantly higher than pre-DSI levels. Additionally, there were no noted adverse outcomes or desaturations when intubation eventually took place in this limited case series. More investigation is required to determine the possible indications for and safety of DSI when performed in various ED settings.

Blind Nasotracheal Intubation

Historically, blind nasotracheal intubation (BNTI) was used extensively in the ED and out-of-hospital setting, but it has fallen out of favor largely because of the superiority of RSI. Prehospital intubation success between RSI and BNTI favors RSI, and ED studies have shown that RSI is superior.[3,16]

In the ED, BNTI rarely, if ever, should be used and is reserved for patients in whom the presence of a narrowly defined type of difficult airway makes RSI undesirable or contraindicated, and alternatives (eg, flexible endoscope) are not available. A review of nearly 9000 ED intubations has shown that nasal intubation was used in only 5% of intubations performed from 1997 to 2002.[16] A current registry of more than 17,500 adult ED intubations between 2002 and 2012 has revealed that this is now less than 0.5%.[3]

Awake Oral Intubation

Awake oral intubation is a technique in which sedative and topical anesthetic agents are administered to permit management of a difficult airway without neuromuscular blockade. Sedation and analgesia are achieved in a manner analogous to that for painful procedures in the ED. Topical anesthesia may be achieved by spray, nebulization, or local anesthetic nerve block. Various sedative agents can be used but ketamine, which provides dissociative anesthesia, analgesia, maintenance of protective airway reflexes, and minimal respiratory depression, is often the best choice (see later, "Pharmacologic Agents"). Aliquots of ketamine at a dose of 0.5 mg/kg IV, titrated to the desired level of sedation and procedural tolerance, is an effective method. Dexmedetomidine (Precedex), a centrally acting alpha receptor blocker, has been used successfully, alone or in combination with benzodiazepines, for awake airway evaluations.[21] A typical dose is 1.0 mg/kg IV infused over 5 to 10 minutes. After the patient is sedated, and topical anesthesia has been achieved, gentle direct videolaryngoscopy or flexible endoscopic laryngoscopy is performed to determine whether the glottis is visible and intubation possible. If the glottis is visible, the patient may be intubated during initial laryngoscopy, or the operator, confident that the glottis can be visualized, may opt to perform RSI to benefit from pretreatment, induction, and paralysis, as might be the case in a head-injured patient.

Awake oral intubation is distinct from the practice of oral intubation with a sedative or opioid agent to obtund the patient for intubation without neuromuscular blockade. This latter technique can be referred to as intubation with sedation alone or, paradoxically, nonparalytic RSI. Intubating conditions and first-attempt success achieved even with deep anesthesia are significantly inferior to what is achieved when neuromuscular blockade is used.[3] In general, the technique of administering a potent sedative agent to obtund the patient's responses and permit intubation in the absence of neuromuscular blockade is ill-advised and inappropriate for endotracheal intubation in the ED, unless performed as part of an awake intubation (see earlier), during which lesser amounts of sedation are typically used.

Oral Intubation Without Pharmacologic Agents

The arrested or near death patient may not require pharmacologic agents for intubation, but even an arrested patient may retain sufficient muscle tone to render intubation difficult. If the glottis is not adequately visualized, administration of a single dose of succinylcholine alone may facilitate laryngoscopy (see earlier, "Decision Making"). Success rates for intubating unconscious unresponsive patients are variable but approach those achieved with RSI, presumably because the patient is in a similar physiologic state (ie, muscle relaxation, no ability to react to laryngoscopy or tube insertion).[3,16] This does not apply to patients who are unconscious from neurologic catastrophe or trauma and those who have overdosed or have other medical causes of coma who warrant an induction agent and are intubated with standard RSI procedures (see earlier).

Pharmacologic Agents

Neuromuscular Blocking Agents

NMBAs are highly water-soluble, quaternary ammonium compounds that mimic the quaternary ammonium group on the acetylcholine (ACh) molecule. Their water solubility explains why they do not readily cross the blood-brain barrier or placenta. NMBAs are divided into two main classes, depolarizing and nondepolarizing agents. The depolarizing agent succinylcholine exerts its effects by binding noncompetitively with ACh receptors on the

motor endplate, causing sustained depolarization of the myocyte while preventing transmembrane potentials from reforming and resisting further stimulation from ACh. The other major class of NMBA comprises the competitive, or nondepolarizing, agents, which bind competitively to ACh receptors, preventing access by ACh and preventing muscular activity. The competitive agents are of two pharmacologically distinct types, steroid-based agents (aminosteroid compounds) and benzylisoquinolines. Each of these basic chemical types has distinct properties, but only aminosteroid compounds are used in the ED.

Succinylcholine. Succinylcholine is a combination of two molecules of ACh. Succinylcholine is rapidly hydrolyzed by plasma pseudocholinesterase to succinylmonocholine, which is a weak NMBA, and then to succinic acid and choline, which have no NMBA activity. Pseudocholinesterase is not present at the motor endplate and exerts its effects systemically before the succinylcholine reaches the ACh receptor. Only a small amount of the succinylcholine administered survives to reach the motor endplate. Succinylcholine is active at the motor endplate until it diffuses away. Decreased plasma pseudocholinesterase activity can increase the amount of succinylcholine reaching the motor endplate, prolonging succinylcholine block, but this is of little significance in the emergency setting because the prolongation of action rarely is significant, reaching only 23 minutes at the extreme.

Uses and Dosing. Succinylcholine is rapidly active, typically producing intubating conditions within 45 seconds of administration by rapid IV bolus injection. The clinical duration of action before spontaneous respiration is 6 to 10 minutes (see Fig. 1.11). Full recovery of normal neuromuscular function occurs within 15 minutes. The combination of rapid onset, complete reliability, short duration of action, and absence of common serious side effects has kept succinylcholine as the drug of choice for most ED intubations. Time-trended surveillance of ED intubation practices has suggested that succinylcholine is slowly being replaced by rocuronium.[3] The use of a competitive or nondepolarizing NMBA for RSI may be desirable when succinylcholine is contraindicated and in certain other settings. The appropriate dose of succinylcholine for emergency airway management is 1.5 mg/kg IV. Although the effective dose at which paralysis is achieved in 95% of patients (ED_{95}) for succinylcholine paralysis is much lower (0.3 mg/kg), the onset of muscle paralysis is excessively long at these lower doses and is not compatible with emergency intubation. Excellent intubating conditions are best achieved when succinylcholine is dosed at 1.5 mg/kg. Multiple studies have confirmed that the dose of succinylcholine is based on the patient's total body weight (TBW) and is not adjusted (downward), regardless of the degree of obesity.[22]

Cardiovascular Effects. As an ACh analogue, succinylcholine binds to ACh receptors throughout the body, not just at the motor endplate. It is difficult to separate the effects of succinylcholine on the heart caused by direct cardiac muscarinic stimulation from those caused by stimulation of autonomic ganglia by succinylcholine and from the effects induced by autonomic responses to laryngoscopy and intubation. Succinylcholine can be a negative chronotrope, especially in children, and sinus bradycardia may ensue after succinylcholine administration. Sinus bradycardia is treated with atropine, if necessary, but is usually self-limiting. Some pediatric practitioners recommend pretreatment with atropine for children younger than 1 year, but there is no evidence for benefit, and we do not agree with this recommendation. Adults may develop bradycardia after administration of a second dose of succinylcholine. Other cardiac dysrhythmias, including ventricular fibrillation and asystole, have been reported with succinylcholine, but it is impossible to distinguish the effects of the drug itself from those caused by the intense vagal stimulation and catecholamine release that accompany laryngoscopy and intubation. In addition, many of these catastrophic complications occur in critically ill patients, further confounding attempts to identify whether the illness or any particular drug or procedure is the cause.

Fasciculations. The depolarizing action of succinylcholine results in fine chaotic contractions of the muscles throughout the body for several seconds during the onset of paralysis in over 90% of patients. Muscle pain occurs in approximately 50% of patients who receive succinylcholine. Although it is has been thought that muscle pains are reduced or abolished by prior administration of a defasciculating dose of a competitive NMBA, the evidence is not conclusive. Use of 1.5 mg/kg of succinylcholine results in less fasciculation and less myalgia than occur with 1 mg/kg.

Hyperkalemia. Succinylcholine has been associated with severe fatal hyperkalemia when administered to patients with specific predisposing clinical conditions (Table 1.2). The mechanism whereby severe hyperkalemia occurs is related to receptor upregulation on the postsynaptic muscle membrane. When a muscle is deprived of ACh stimulation for several days, receptor upregulation occurs, causing an increase in receptor density and a change of receptor subtypes on the muscle surface. ACh receptors are primarily K^+ ion channels, and at-risk patients can have an immediate massive efflux of potassium as these newly recruited receptors are depolarized by succinylcholine. This occurs predominantly at the site of injury but may also occur in tissue remote from the original insult.[23] Although the hyperkalemia occurs within minutes after administration of succinylcholine and may be severe or fatal, the patient's vulnerability to succinylcholine-induced hyperkalemia starts as early as 3 days but does not become significant until more than 5 days after the inciting injury or burn, because receptor upregulation production of protein subunits takes time develop.

Succinylcholine remains the agent of choice for RSI in acute burn, trauma, stroke, and spinal cord injury if intubation occurs earlier than 5 days after onset of the condition. If doubt exists regarding the onset time, succinylcholine should be replaced with a competitive NMBA, usually rocuronium. Degenerative neuromuscular disorders, denervation syndromes, or primary myopathies (eg, multiple sclerosis, amyotrophic lateral sclerosis, Duchenne muscular dystrophy) can be particularly troubling, however, because the risk begins the onset of the disease and continues indefinitely, regardless of the apparent stability of the symptoms. In patients with denervation caused by a sudden discreet injury or ischemic insult (eg, stroke, spinal cord injury), the upregulated receptors eventually regress, and the patient can safely receive succinylcholine beginning 6 months after the original insult.

Potassium release does not occur to any significant extent in the general population. Succinylcholine is not contraindicated in renal failure but probably should not be used in patients with known or presumed hyperkalemia (often in the setting of missed

TABLE 1.2

Conditions Associated With Hyperkalemia After Succinylcholine Administration

CONDITION	PERIOD OF CONCERN
Burns > 10% BSA	>5 days until healed
Crush injury	>5 days until healed
Denervation (stroke, spinal cord injury)	>5 days until 6 mo postinjury
Neuromuscular disease (ALS, MS, MD)	Indefinitely
Intraabdominal sepsis	>5 days until resolution

ALS, Amyotrophic lateral sclerosis; *BSA,* body surface area; *MD,* muscular dystrophy; *MS,* multiple sclerosis.

dialysis) sufficient to be manifest on the electrocardiogram (ECG). Treatment for succinylcholine-induced hyperkalemia is the same as for any other hyperkalemic emergency.

Masseter Spasm. Succinylcholine has rarely been reported to cause masseter spasm, primarily in children and young adults. The clinical significance of this phenomenon is unclear, but administration of a competitive NMBA terminates the spasm. Severe persistent spasm should raise suspicion of malignant hyperthermia.

Malignant Hyperthermia. Succinylcholine has been associated with malignant hyperthermia, a perplexing syndrome of rapid temperature rise and rhabdomyolysis. Malignant hyperthermia occurs in genetically predisposed individuals who receive certain volatile anesthetic agents or succinylcholine. The condition is extremely rare and has not been reported in the context of ED intubation. Treatment consists of cessation of any potential offending agents, administration of dantrolene (1–2.5 mg/kg IV every 5 minutes, to a maximum dose of 10 mg/kg IV), and attempts to reduce body temperature by external means. A national malignant hyperthermia hotline is available for emergency consultation at 1-800-644-9737 (then dial 0).

Competitive Agents. Competitive NMBAs are classified according to their chemical structure. The aminosteroid agents include pancuronium, vecuronium, and rocuronium. Vecuronium neither releases histamine nor exhibits cardiac muscarinic blockade and is an excellent agent for the maintenance of neuromuscular blockade when this is desirable. Rocuronium is the best agent for use in RSI when succinylcholine is contraindicated. In a study of ED intubations performed with rocuronium or succinylcholine, first-pass intubation success was independent of the NMBA used.[24]

Rocuronium. When a patient has a contraindication to succinylcholine, rocuronium bromide is the paralytic agent of choice. At a dose of 1.0–1.2 mg/kg IV, rocuronium achieves intubating conditions similar to those of succinylcholine, lasts approximately 50 minutes, and has been used in the ED with success.[3] Intubating level paralysis may take 15 to 20 seconds longer than with succinylcholine, and the operator should allow 60 seconds to elapse before attempting intubation when rocuronium is used. There are no absolute contraindications to rocuronium. In the ED, dosing in morbidly obese patients should be based on actual TBW. Although adequate intubating conditions can be obtained when ideal body weight (IBW) is used, this concept is only pertinent to the anesthesiologist who may be titrating neuromuscular blockade to a short anesthetic time. Paralysis will be of sufficient duration, regardless of which weight-based dosing regimen is used, that the emergency clinician will need to have managed the airway successfully before spontaneous respirations return. The potential for inferior intubating conditions using IBW dosing makes this approach undesirable. However, in the subset of critically ill patients who require frequent, serial, neurologic examinations, the more prolonged duration of paralysis with rocuronium may make it less desirable than succinylcholine for routine use.

Paralysis After Intubation. After intubation, prolonged paralysis may be desired to optimize mechanical ventilation; however, current management is based on use of deep sedation and analgesia, with neuromuscular paralysis used only when necessary to maintain ventilatory control. If neuromuscular blockade is required, vecuronium (0.1 mg/kg IV) can be given, but longer term neuromuscular blockade is not to be undertaken without ensuring appropriate sedation and analgesia of the patient and a means to ensure that ongoing sedation and analgesia are adequate. Prolonged paralysis without adequate sedation occurs in up to 20% of patients following RSI in the ED.[25] A sedating dose of a benzodiazepine, such as midazolam (0.1 mg/kg IV), combined with an opioid analgesic, such as fentanyl (3–5 μg/kg IV) or morphine (0.2–0.3 mg/kg IV), is required to improve patient comfort and decrease sympathetic response to the ETT. A sedative strategy using propofol (0.1 mg/kg/min IV) is common, especially in head-injured patients, because of its beneficial cerebroprotective profile and rapid resolution of anesthesia that allows frequent neurologic reassessments. With appropriate attention to achieving optimal sedation and analgesia, ongoing use of an NMBA usually is not necessary.

Induction Agents

A patient with any degree of clinical responsiveness, including reactivity to noxious stimuli, should receive a sedative or induction agent at the time of administration of any NMBA. Patients who are deeply unconscious and unresponsive may require only a reduced dose of an induction agent if the unconscious state is caused by drugs or alcohol, which are themselves general anesthetic agents. Patients who are unconscious because of a central nervous system insult should receive a full induction dose of an appropriate agent to attenuate adverse responses to airway manipulation. Induction agents also potentiate the effect of the NMBA and improve intubation conditions because the intubation is often initiated on the leading edge of paralysis, and the relaxation effects of the induction agent are additive to those of the NMBA.

Etomidate. Etomidate is an imidazole derivative that has been in use since 1972. Its activity profile is similar to that of thiopental, with rapid onset, rapid peak activity, and brief duration, but it is remarkable in its lack of adverse hemodynamic effects. Emergency clinicians have high confidence in etomidate and, over the last decade, have chosen it for more than 90% of all ED intubations.[3] The induction dose is 0.3 mg/kg IV. Because etomidate is able to decrease ICP, cerebral blood flow (CBF), and cerebral metabolic rate without adversely affecting systemic mean arterial blood pressure and cerebral perfusion pressure (CPP), it is an excellent induction agent for patients with elevated ICP, even in cases of hemodynamic instability. Etomidate may cause brief myoclonus, but this is of no clinical significance when administered for RSI. A single dose of etomidate has been shown to reduce serum cortisol levels transiently and blunt the adrenal response to adrenocorticotropic hormone (ACTH) by reversibly inhibiting 11β-hydroxylase, a key synthetic enzyme in the glucocorticoid pathway. Since discovering this mechanism, much debate has emerged regarding etomidate's impact on survival in sepsis patients. Data from retrospective studies are conflicting, but a recent meta-analysis of 18 prospective observational and controlled trials has shown no mortality effect from a single dose of etomidate in septic patients.[26,27] Recent prospective randomized trials looking at undifferentiated ICU admissions and those specifically involving individuals with septic shock have shown that single-dose etomidate has no effect on outcome.[28] Ironically, much of the original criticism of etomidate arose from the hypothesis that the adrenocortical response to exogenous corticotropin predicts outcome in patients with septic shock, a theory that has since been discredited.[28a] The most comprehensive study of the role of exogenous corticosteroids in septic shock has failed to show any benefit, casting further doubt about any possible mortality effect of a single dose of etomidate. Pending a properly constructed, prospective, randomized clinical trial, there is not sufficient evidence to support the recommendation that etomidate be avoided in patients with septic shock. In fact, etomidate's superior hemodynamic profile makes it an excellent choice in these and other unstable patients.

Ketamine. Ketamine, a phencyclidine derivative, has been widely used as a general anesthetic agent since 1970. After an IV dose of 1 to 2 mg/kg, ketamine produces loss of awareness within 30 seconds, peaks in approximately 1 minute, and has a clinical

duration of 10 to 15 minutes. As a dissociative anesthetic agent, ketamine induces a cataleptic state rather than a true unconscious state. The patient has profound anesthesia but may have her or his eyes open. Protective airway reflexes and ventilatory drive usually are preserved.

The principal uses of ketamine in emergency airway management are as a sedative agent for awake intubation (eg, flexible bronchoscope) and as the induction agent during RSI for patients with acute severe asthma or hemodynamic instability. Because of its superior hemodynamic profile, ketamine is an excellent alternative to etomidate for a hemodynamically unstable patient, such as a patient with sepsis or multiple trauma. Although comparative human evidence is lacking, ketamine probably has less propensity to exacerbate hemodynamic instability than any other agent, even etomidate. However, all sedative induction agents, including ketamine, can provoke further hypotension or cardiovascular collapse in patients with profound refractory shock or those with depressed myocardial contractility and catecholamine depletion. In these settings, dosages are reduced to 50% or 25% of the usual dose. In patients with status asthmaticus, etomidate, propofol, or another induction agent can be used, with the notable exception of sodium thiopental, which releases histamine. Ketamine has some bronchodilatory effects and also can cause catecholamine release, so it may be useful for intubation and intermittent administration as part of sedation for mechanical ventilation in patients with severe asthma, although no outcome studies have clearly demonstrated its superiority.

Controversy exists regarding the use of ketamine in patients with elevated ICP because it may increase the cerebral metabolic rate, ICP, and CBF. The evidence that ketamine can produce harm in this way is conflicting, however, and may be outweighed in trauma patients because of its overall favorable hemodynamic profile.[29] Ketamine does not appear to be harmful in children when given in procedural doses to patients with known elevated ICP and may actually lower ICP.

Because it may cause release of catecholamines and increase blood pressure, ketamine should be avoided in traumatic brain injury (TBI) patients with elevated blood pressure. However, we recommend the use of ketamine or etomidate during RSI for induction of patients with TBI and hypotension or risk factors for hypotension. Ketamine may produce unpleasant emergence phenomena, especially disturbing or frightening dreams in the first 3 hours after awakening. These reactions, which are more prominent in adults than in children, in women than in men, in patients receiving larger doses, and in certain personality types, may be mitigated by benzodiazepine administration.[30] Patients who undergo RSI with ketamine should receive a benzodiazepine (eg, lorazepam, 0.05 mg/kg, or midazolam, 0.1 mg/kg) as part of postintubation management.

Propofol. Propofol is a highly lipophilic alkylphenol with γ-aminobutyric acid (GABA) receptor stimulation activity. Its primary use in the emergency setting has been for postintubation sedation in head-injured patients; however, it increasingly has been used as an induction agent during RSI.[3] It reduces ICP and cerebral oxygen usage and is indicated for patients with elevated ICP caused by a medical or traumatic emergency. Because of the propensity of propofol to cause hypotension through vasodilation and direct myocardial depression, the dosage is reduced or the drug is avoided altogether in hemodynamically compromised patients. The usual induction dose of propofol is 1.5 mg/kg IV, but reduced dosages should be used in older patients or those with hemodynamic compromise or poor cardiovascular reserve. Propofol is delivered in a soybean oil and lecithin vehicle and should not be used for patients with allergies to these substances. Although propofol has traditionally been avoided in patients with egg allergy, it is likely safe unless a history of anaphylaxis to egg protein exists. Propofol causes pain at the site of administration in as many as 60% of patients. Using a proximal (antecubital) vein in lieu of a distal venous injection site is the most important preventive measure. Pretreatment with IV lidocaine, coadministration of lidocaine mixed with propofol, and pretreatment with opioids or ketamine have all been shown to limit this common adverse reaction.[31]

Other Induction Agents. Given the widespread acceptance and familiarity with etomidate, propofol, and ketamine, other drug classes such as barbiturates and benzodiazepines are infrequently used as induction agents for RSI. In North America, nearly all emergency intubations are performed with one of those three agents.[3] Rapidly acting barbiturates, such as thiopental, are highly lipid-soluble and readily cross the blood-brain barrier, acting on the GABA receptor neuroinhibitory complex to depress central nervous system activity. The last US-based manufacturer of sodium thiopental stopped production, and imports into the United States are severely restricted, but it is still in use in some areas outside of North America. Of the benzodiazepines, only midazolam is used as an induction agent, a role for which it is inferior to other, more commonly used agents, such as etomidate and propofol. The usual induction dose for midazolam is 0.2 to 0.3 mg/kg IV. At a dose of 0.3 mg/kg IV, midazolam produces loss of consciousness in about 30 seconds (but may take up to 120 seconds) and has a clinical duration of 15 to 20 minutes. Midazolam is a negative inotrope and should be used with caution in hemodynamically compromised and older patients, for whom the dose can be reduced to 0.1 or 0.05 mg/kg. Onset is slower at these reduced doses.

Dexmedetomidine (Precedex) has gained popularity as a solo agent, or in combination with benzodiazepines, for procedural sedation and awake intubation.[21] The typical loading dose is 1 mg/kg IV over 5 to 10 minutes. At therapeutic levels, it has a minimal effect on the respiratory drive or protective airway reflexes but its use is limited by bradycardia and hypotension. It has not been studied as an induction agent during RSI, and its slow loading rate would likely keep it from being effective in that situation.

Special Clinical Circumstances

This section will discuss several specific clinical scenarios that often warrant modification of the airway management plan. Pediatric airway management is discussed in Chapter 161.

Status Asthmaticus

RSI is the recommended technique for intubation of a patient in status asthmaticus. Difficult airway considerations are complex in an asthmatic patient because of impending respiratory arrest and the patient's inability to tolerate attempts at awake intubation. When a difficult airway is identified, intubation preparation should begin early, so that awake methods, such as flexible endoscopic intubation, may be retained as options. Even when a difficult airway is identified in an asthmatic patient, however, RSI usually is the intubation method of choice. Ventilation with a BMV or EGD may be difficult because of high airway resistance, and the technique should be optimized with the use of a low tidal volume and respiratory rate, with a high inspiratory flow rate. Reducing the respiratory rate to allow for adequate exhalation, even at the expense of retaining CO_2, is recommended to prevent the development of auto-PEEP, known as breath stacking, which can compromise ventilation and cause barotrauma.

The asthmatic patient has highly reactive airways, and steps should be taken to minimize any additional bronchospasm that may occur during intubation. The bronchoconstriction that occurs with ETT placement is thought to be neurally mediated,

and local anesthetics, particularly lidocaine, have been studied as a way to blunt this airway reflex. We had previously recommended lidocaine to suppress the reflexive bronchospasm and coughing that occurs in response to airway manipulation in asthmatic patients, but there have been no high-level human studies supporting these beneficial effects, particularly in patients who have received a β_2-agonist. High-dose, inhaled β-agonists, such as albuterol, provide maximal protection against reactive bronchospasm during intubation and are indicated for asthmatics with or without active bronchospasm. Ketamine has bronchodilatory properties and may mitigate bronchospasm in patients who are not intubated and in patients who are already intubated and are not improving with mechanical ventilation. Although studies to date have been limited, ketamine is also a reasonable induction agent for the emergency intubation of patients with status asthmaticus (Table 1.3).

Hemodynamic Consequences of Intubation

Laryngoscopy and intubation are potent stimuli for the reflex release of catecholamines. This RSRL produces a modest increase in blood pressure and heart rate and is of little or no consequence in otherwise healthy patients. The RSRL is of potential clinical significance in two settings, acute elevation of ICP and certain cardiovascular diseases (eg, intracerebral hemorrhage, subarachnoid hemorrhage, aortic dissection or aneurysm, ischemic heart disease). In these settings, the reflexive release of catecholamines, increased myocardial oxygen demand, and attendant rise in mean arterial blood pressure and heart rate may produce deleterious effects. The synthetic opioids (eg, fentanyl) and β-adrenergic blocking agents (eg, esmolol) are capable of blunting the RSRL and stabilizing heart rate and blood pressure during intubation. In patients at risk from acute blood pressure elevation, administration of fentanyl (3 μg/kg) during the pretreatment phase of RSI attenuates the heart rate and blood pressure increase. The full sympatholytic dose of fentanyl is much higher, but limiting the dose minimizes the likelihood of precipitating or worsening hypoventilation. Because fentanyl reduces sympathetic tone, it should not be given to patients with hemodynamic compromise (eg, bleeding, volume depletion, sepsis). The administration of 3 μg/kg is safer than larger doses and can be supplemented with an additional 3 μg/kg immediately after intubation if greater sympathetic blockade is desired or hypertension and tachycardia persist. Fentanyl should be given over 60 seconds to prevent hypoventilation or apnea.

TABLE 1.3

Rapid Sequence Intubation for Status Asthmaticus

TIME	STEP
Zero minus 10 min	Preparation
Zero minus 5 min	Preoxygenation (as possible) • Continuous albuterol nebulizer • 100% oxygen for 3 min or eight vital capacity breaths, or highest flow oxygen possible
Zero minus 3 min	Pretreatment—albuterol, 2.5 mg nebulized, or lidocaine, 1.5 mg/kg[a]
Zero	Paralysis with induction • Ketamine, 1.5 mg/kg • Succinylcholine, 1.5 mg/kg
Zero plus 30 s	Positioning
Zero plus 45 s	Placement • Laryngoscopy with intubation • End-tidal carbon dioxide confirmation
Zero plus 2 min	Postintubation management • Sedation and analgesia • NMBA only if required after adequate sedation, analgesia • In-line albuterol nebulization • Additional ketamine as indicated

[a]Only if not already pretreated with β-agonists.
NMBA, Neuromuscular blocking agent.

Elevated Intracranial Pressure

When the ICP is elevated as a result of head injury or acute intracranial catastrophe, there are two considerations—maintaining CPP (by avoiding excessive hypotension) and minimizing supranormal surges in the mean arterial blood pressure (MAP), which can increase ICP. Normally, cerebrovascular autoregulation maintains a constant CBF over a wide range of systemic blood pressures, but this action may be lost in conditions that elevate ICP. Maintenance of the systemic MAP at 100 mm Hg or higher supports CPP and reduces the likelihood of secondary injury. Therefore, the RSI induction agent for a patient with suspected elevated ICP should be selected and dosed to minimize the likelihood of exacerbation of hypotension. In patients with suspected or documented elevation of ICP, control of RSRL is desirable to avoid further elevation of ICP. Fentanyl (3 μg/kg) given as a pretreatment drug is the best choice for this purpose in the emergency setting.

Although evidence has suggested a separate reflex that increases ICP in response to laryngoscopy and intubation, and IV lidocaine was formerly recommended for this purpose, evidence is weak, and no further evidence has developed. Therefore, we no longer recommend lidocaine in this setting. Similarly, RSRL and the ICP response to intubation make blind nasotracheal intubation inadvisable for brain injury patients.

In emergency patients who may have elevated ICP, the emergency clinician should choose an induction agent that balances a favorable effect on cerebral dynamics and ICP with a stable systemic hemodynamic profile. We recommend etomidate, although propofol is also a good option when there is no hemodynamic compromise (Table 1.4).

Hypotension and Shock

In critically ill and injured patients, induction agents have the potential to exaggerate preexisting hypotension and, in some cases, precipitate circulatory collapse. Peri-intubation cardiac arrest, typically pulseless electrical activity (PEA), complicates up to 4% of emergency RSIs.[3] Risk factors in ED populations include advanced age (>70 years), COPD, and shock on arrival.[32-34] In patients with profound shock, all induction agents have the potential to exacerbate hypotension. Shock-sensitive RSI hinges on three primary management principles—volume resuscitation prior to induction (if time permits), reduced dose induction agent administration, and pretreatment with peri-intubation pressor agents (Table 1.5).

When time allows, patients with hypotension should be administered isotonic fluid boluses or packed red blood cells (PRBCs) to maximize preload, increase blood pressure, and allow more pharmacologic options during RSI. Phenylephrine hydrochloride (Neo-Synephrine; 50–100 μg IV push) administered prior to the induction agent can limit hypotensive effects. In addition, induction agent selection should be limited to etomidate or ketamine only, and the dose should be reduced by 50%. Attention to these details can reduce the incidence of cardiovascular peri-intubation adverse events.

TABLE 1.4

Rapid Sequence Intubation for Elevated Intracranial Pressure

TIME	STEP
Zero minus 10 min	Preparation
Zero minus 5 min	Preoxygenation (as possible) — 100% oxygen for 3 min or eight vital capacity breaths
Zero minus 3 min	Pretreatment—fentanyl, 3 μg/kg (slowly)
Zero	Paralysis with induction • Etomidate, 0.3 mg/kg • Succinylcholine, 1.5 mg/kg[a]
Zero plus 30 s	Positioning
Zero plus 45 s	Placement • Laryngoscopy with intubation • End-tidal carbon dioxide confirmation
Zero plus 2 min	Postintubation management—sedation and analgesia; consider propofol to permit frequent reexamination NMBA only if required after adequate sedation, analgesia

[a]May substitute rocuronium, 1 mg/kg, for succinylcholine.
NMBA, Neuromuscular blocking agent.

TABLE 1.5

Rapid Sequence Intubation for Hypotension and Shock

TIME	STEP
Zero minus 10 min	Preparation—isotonic fluid boluses or blood products
Zero minus 5 min	Preoxygenation (as possible)—100% oxygen for 3 min or eight vital capacity breaths
Zero minus 3 min	Pretreatment—phenylephrine hydrochloride (Neosynephrine), 50–100 μg IV push (if still hypotensive after IVFs or blood)
Zero	Paralysis with induction • Ketamine, 0.5–0.75 mg/kg OR Etomidate, 0.1–0.15 mg/kg • Succinylcholine, 1.5 mg/kg IV
Zero plus 30 s	Positioning
Zero plus 45 s	Placement • Laryngoscopy with intubation • End-tidal carbon dioxide confirmation
Zero plus 2 min	Postintubation management—continued volume resuscitation

Potential Cervical Spine Injury

Historically, most patients with suspected blunt cervical spine injury were intubated orally by direct laryngoscopy with in-line cervical spine immobilization, whether done as an awake procedure or with neuromuscular blockade. However, with this approach, glottic views can be inadequate, and excessive lifting force often is required. Patients with known cervical spine fractures are optimally managed with a flexible bronchoscope to minimize cervical spine motion; however, in the emergency setting, a videolaryngoscope should be used and, if not available, a direct laryngoscope also can be used. A videolaryngoscope provides superior laryngeal views without excessive lifting force or cervical spine movement and has higher intubation success rates when compared with conventional direct laryngoscopy.

The intubating laryngeal mask airway (ILMA) also may result in less cervical spine movement during intubation than direct laryngoscopy, although the need for a blind intubation devices has been decreasing with the advent of videolaryngoscopy.[3] Other devices have also shown promise for safe intubation of patients with cervical spine injury. A fluoroscopic study in which intubation with the Shikani optical stylet (SOS; Clarus Medical, Minneapolis) was compared with DL has shown significantly less cervical spine movement with the SOS but a slightly longer intubation time (28 vs. 17 seconds). Video-enhanced rigid stylets, such as the Clarus Video System (CVS) are also effective tools for patients in cervical collars.[35] The Airtraq and Pentax Airway Scope are curved intubation devices that integrate an ETT channel and either a viewing lens or a video screen to facilitate intubation. Both devices have shown high levels of intubation success and minimal cervical spine motion compared with direct laryngoscopy. In the absence of a coexistent blunt traumatic mechanism or a neurologic examination indicating spinal cord injury, cervical spine immobilization for intubation of patients with penetrating head and neck trauma rarely is indicated. It is not proven whether patients with gunshot or shotgun injuries to the head or neck are at risk of exacerbation of cervical cord injury during intubation, and there is no report of such a patient, with or without clinical evidence of spinal cord injury, who was injured by intubation. In addition, cervical spine immobilization in patients with penetrating neck injuries may be harmful. A large retrospective review of more than 45,000 trauma patients with penetrating injuries has found that those in whom prehospital cervical collars were applied were two to three times more likely to die. Delays in transport and patient assessment and added difficulty for airway procedures were postulated as potential contributors.[36]

Airway Devices and Techniques

Direct Versus Video Laryngoscopy

The inherent limitations of DL make glottic visualization less likely when compared to video instruments.[6,37] Videolaryngoscopes offer the ability to visualize the glottis without creating a direct line of sight, thus making irrelevant many of the issues that complicate DL. Although DL remains an acceptable technique for tracheal intubation, there is mounting evidence of the clear superiority of modern video devices, and DL increasingly is relegated to the role of a standby device.[3]

Videolaryngoscopes

Modern laryngoscopes incorporate video imaging into specially designed laryngoscope blades to provide glottic visualization superior to that of a direct laryngoscope, without the need to create a straight-line visual axis through the mouth. Videolaryngoscopes can be separated into two large groups based on shape—those that use traditional laryngoscope geometry complemented by a video viewing device (which also can be used as direct laryngoscopes), and those with specially curved or angulated blades, designed specifically for use in a video system and not suitable for DL. This classification system is important because intubating mechanics and success differ between the two groups. Nevertheless, regardless of type, videolaryngoscopes provide superior glottic views and greater first-pass success when compared with direct laryngoscopes, particularly when the airway is difficult or when a nonexpert operator is performing the intubation.[6,7,37,38]

For routine intubation of nondifficult airways by expert intubators, success rates with direct laryngoscopy often can match those obtained with a videolaryngoscope.[7] Because emergency intubations are by definition emergent and cannot be rescheduled, operator experience varies, and airways are often difficult, videolaryngoscopy is the first-choice modality for emergency intubations.

The GlideScope videolaryngoscope system (GVL; Verathon, Seattle) uses a modified Macintosh blade with a straightened, angulated, and elongated tip enclosing a proximally placed camera to provide a wide-angle view of the glottis and surrounding anatomy, even in patients with difficult airways. Video images are transmitted to a high-resolution display that can record still pictures and video clips. Handle and blade sizes range from neonate to obese adult. The GlideScope Ranger is an ultraportable version of the device, designed for use in the out-of-hospital environment. One large series of out-of-hospital intubations has shown that the Ranger significantly reduces the number of attempts needed to intubate compared with DL.[39] The GlideScope Cobalt is a system designed for a single use, without the need for cleaning (Fig. 1.12). It consists of a flexible video wand insert that fits inside a disposable, single-piece transparent blade called a stat and comes in sizes comparable to those for the standard GlideScope. The added bulk created by the stat can make it harder to maneuver in emergency patients and may reduce intubation success compared to the standard GVL blade.[40] The newest generation GlideScope handles are made of lightweight titanium, with a narrower side profile (Fig. 1.13). The placement of the camera distally along the blade to create a viewing field essentially negates the obstructive potential of the tongue, so GlideScope laryngoscopy and most other hyperangulated videolaryngoscopy is performed with the blade introduced in the midline of the mouth and advanced around the tongue, with very little lifting. A proprietary rigid, preformed stylet is available for use with the GlideScope, or a malleable stylet can be shaped to match the exaggerated curve of the GlideScope blade. The rigid stylet is less likely to deform during intubation attempts and allows the operator better ETT control on the video screen. Either stylet may be used, and data are conflicting regarding the advantage provided with a rigid stylet; however, one ED-based investigation has suggested that intubation success is higher with the rigid stylet compared with a standard malleable stylet.[41,42] When compared with DL, the GlideScope provides an equivalent or superior glottic view and has a very high intubation success rate.[7] Traditional predictors of difficult direct laryngoscopy likely will not apply to videolaryngoscopy because most are based on limitations of creating a direct line of sight, which is not part of videolaryngoscopy.[43]

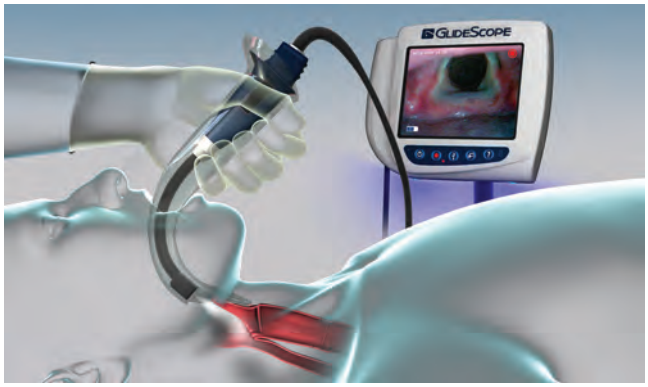

Fig. 1.12. GlideScope Cobalt system uses a high-resolution digital display, includes single-use Stats (blade sheaths) that cover the video baton, and can record still images and video clips through internal and removable storage devices. (Courtesy Verathon, Seattle.)

Although the view is universally better with all videolaryngoscopes, the GlideScope's impact on first-pass success has been less clear. A recent large meta-analysis of more than 12 studies has shown that GVL is superior in obtaining full glottic views but, for experienced laryngoscopists, first-pass success was not superior to conventional laryngoscopy.[7] In ED patients, GVL was associated with a lower first-attempt success rate than DL, although the groups were not matched.[3] Single-center ED observational studies, however, have shown that the GlideScope is superior to DL for intubating ED patients, and success has increased over time.[37,44] The GlideScope causes less cervical spine movement than conventional DL and provides better glottic exposure in patients with strict cervical spine precautions. The C-MAC videolaryngoscope (Fig. 1.14; Karl Storz Endoscopy, Tuttlingen, Germany)

Fig. 1.13. GlideScope Titanium handles incorporate similar video elements in a lightweight titanium blade with a narrower side profile. Connection to the video display is made by a USB-style cord. (Courtesy Verathon, Seattle.)

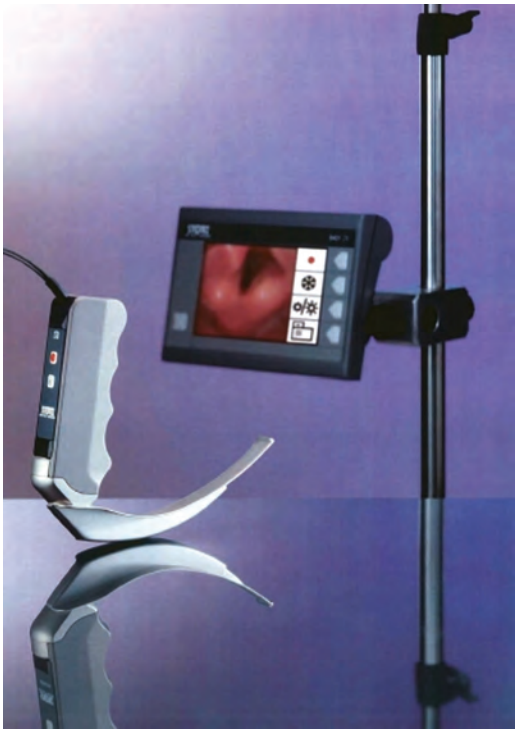

Fig. 1.14. The C-MAC videolaryngoscope (Karl Storz Endoscopy, Tuttlingen, Germany) uses an integrated complementary metal oxide semiconductor (CMOS) video chip to capture a video image from near the distal tip of an otherwise conventional laryngoscope blade. The image is conveyed to a video screen, where it is viewed by the intubator. (From Walls RM, Murphy MF, eds: Manual of emergency airway management, ed 4, Philadelphia, 2012, Lippincott, Williams & Wilkins; with permission.)

Fig. 1.15. King Vision videolaryngoscope integrates a single-use, curved video blade attached to a top-mounted display. The blades come in two versions, those with endotracheal tube channels, for advancing the endotracheal tube, and those without. (Courtesy Calvin A. Brown III, MD.)

Fig. 1.16. The Clarus Video System incorporates a curved stylet containing a CMOS chip video camera surrounding by a malleable but rigid protective metal sheath. Images are displayed on a video screen attached to the handle. The screen can swivel for optimal viewing as the stylet is inserted into the mouth. (Courtesy Clarus Medical, Minneapolis.)

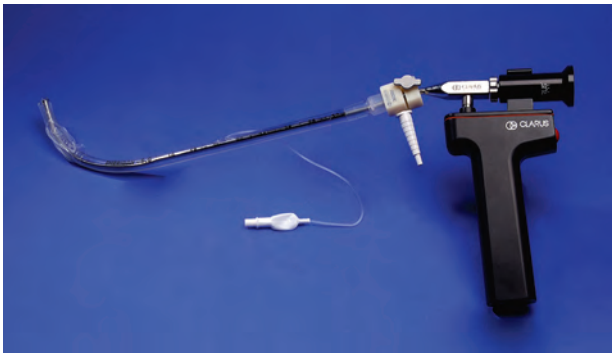

Fig. 1.17. The Shikani optical stylet (SOS) with endotracheal tube mounted. The eyepiece and battery pack are at the *right*. (Courtesy Clarus Medical, Minneapolis, MN.)

incorporates a complementary metal oxide semiconductor (CMOS) video chip into a range of laryngoscope blades to enhance glottic views. Images are displayed on a high-resolution monitor, with image- and video-saving capabilities. The traditionally shaped C-MAC blade can be used as a direct laryngoscope by a trainee while a supervisor observes the video output, providing an excellent tool for teaching DL. One ED-based direct comparison of the C-MAC and GVL has suggested that they perform similarly during emergency intubation.[45] Compared to DL the C-MAC provides better visualization of the glottic inlet, higher rates of first-pass success, and outperforms DL when rescuing a failed first attempt using DL.[3,6,46]

The King Vision videolaryngoscope (King Systems, Noblesville, IN) is a single-use, lightweight device with a detachable (and reusable) screen that sits on top of a disposable video blade (Fig. 1.15). There are two blade types, one with an integrated tube channel and one without; the latter requires the operator to place the ETT manually. In simulated difficult airways using cadaveric subjects, the King Vision results in higher success rates and faster tube placement compared to DL.[47] The McGrath Series 5 is a cordless videolaryngoscope with an integrated screen and handle configuration.

There are several other models of videolaryngoscopes with various sizes and features, such as disposable sheaths or blades, and at various price points.[48,49] Individual evaluation of these devices is important in selecting the best videolaryngoscope for an individual practitioner or practice group. In 2012, videolaryngoscopes were chosen as the first device for airway management in nearly 40% of all intubations.[3] Overall, videolaryngoscopy offers the promise of transforming laryngoscopy and has the potential to render DL obsolete.

Fiberoptic and Video Intubating Stylets

Several semirigid fiberoptic and video intubating stylets also are available. The SOS is the most studied of these, although a newer video device (Clarus Video System, Clarus Medical, Minneapolis; Figs. 1.16 and 1.17) based on the same principles likely will perform as well as or better than its fiberoptic forerunner. The ETT is placed over a semirigid stylet, consisting of a metal sheath with a distally placed video image acquisition system, then advanced through the mouth and over the tongue in the midline and into the trachea under fiberoptic or video visualization. The SOS appears to cause less movement of the cervical spine than conventional laryngoscopy during intubation with inline stabilization (Fig. 1.16). A smaller version, the Levitan scope (Clarus Medical), uses a light-emitting diode (LED)–illuminated fiberoptic stylet to facilitate intubation by direct laryngoscopy. The device is recommended by the manufacturer to facilitate first-pass success when a limited glottic view is obtained by DL. In the only study comparing the Levitan scope with the gum elastic bougie, however, the two devices achieved similar success.

Flexible Intubating Scopes

Intubation using a flexible endoscope is an important option for certain difficult airways, particularly in those with distorted upper airway anatomy, such as angioedema or blunt anterior neck trauma. These scopes long relied on fiberoptic technology, but this has largely been supplanted by miniaturized, high-quality video systems (Fig. 1.18). After appropriate patient preparation, the endoscope is passed through the vocal cords under continuous visualization, serving as an introducer for an ETT, which is then placed through the glottis. Flexible endoscopic examination also is used for airway assessment to determine whether intubation is needed, such as for patients with smoke inhalation or supraglottitis. Intubation of morbidly obese patients, those with distorted airway anatomy (eg, penetrating or blunt anterior neck injury), or those with a fixed cervical spine deformity can be achieved with the flexible endoscope with topical anesthesia and judicious sedation, thus preserving the patient's ability to breathe until intubation has been achieved. Scopes also have been used successfully to intubate through an ILMA, and video systems likely would work well in this application also.

Fig. 1.18. New video flexible bronchoscopes are now available and integrate fully with the C-MAC high-resolution display. (Courtesy Karl Storz Endoscopy, Tuttlingen, Germany.)

Fig. 1.19. The Ambu aScope is a new, fully disposable video flexible bronchoscope with an integrated suction port and working channel for suctioning and instillation of local anesthetic. Airway images are viewed via a reusable digital display. (Courtesy Calvin A. Brown III, MD.)

There is a significant learning curve for flexible endoscopic intubation, and proficiency with this device requires training and practice. Fortunately, endoscopic examination of the upper airway to the level of the vocal cords is a similar skill set as that needed to maneuver the scope through the cords to intubate. This is an important alternative method to obtain real-life experience with insertion and manipulation of the scope. Only approximately 1% of ED patients are managed with a flexible bronchoscope, possibly reflecting reluctance to select this instrument if the operator does not feel sufficiently trained or competent. Flexible bronchoscope intubations are the method of choice for most patients with upper airway obstruction.[3] The role of flexible endoscopic intubation in the ED will likely expand as obesity increases in the population and, increasingly, difficult airways are handled in the ED without backup. The transition from fiberoptic to CMOS video technology will make these flexible scopes more durable and less prone to fogging, both desirable attributes for emergency intubation. Although the cost required to purchase and maintain a flexible endoscope can make it challenging for some emergency departments, single-use flexible videoscopes, such as the Ambu aScope (Ambu, Columbia, MD), provide a less costly option (Fig. 1.19). Emergency clinicians should have immediate access to flexible endoscopes and should acquire training and regular practice in their use.

Extraglottic Devices

Laryngeal Mask Airways. LMAs collectively include a number of commercially available ovoid, silicone mask devices designed to seal above the glottis and permit ventilation through a central channel with a standard bag. There are several models available, and attributes differ among the models, but use and success rates are very similar. The most widely used is the original LMA. Reusable and single-use configurations, conventional and intubating formats, are offered by several manufacturers. The mask is inserted blindly into the pharynx and then inflated, providing a seal that permits ventilation of the trachea with minimal gastric insufflation. In elective anesthesia, the LMA has an extremely high insertion success rate and low complication rate, including a low incidence of tracheal aspiration. Evaluations of LMA insertion by experienced and inexperienced personnel consistently have shown ease of insertion, high insertion success rates, and successful ventilation. The LMA may be a viable alternative to endotracheal intubation for in-hospital or out-of-hospital treatment of cardiac arrest, particularly when responders are inexperienced airway managers. At a minimum, the device may serve a temporizing role equal or superior to BMV until definitive airway management can be achieved. The LMA Supreme (Teleflex Inc., Morrisville, NC) is a more robust LMA with a rigid angled tube, similar to an ILMA; it offers an orogastric tube channel and higher seal pressures than the standard LMA. This likely is the best version for general ED use.

A noninflatable LMA, the i-gel (Intersurgical, Berkshire, England), has a viscous gel cuff and does not require inflation (Fig. 1.20). It is available in a variety of sizes for adults and pediatric patients. The device is placed blindly, and insertion depths are marked on the side of the device. It has an integrated bite block and channel for passage of an orogastric tube. Initial experience with the device, even with minimally trained novice users, has been promising, with high insertion success rates and shorter insertion times when compared with the LMA or laryngeal tube airway.[50]

The ILMA is designed to facilitate intubation through the mask after correct placement (Fig. 1.21). It differs from the LMA in two main ways. First, the mask is attached to a rigid, stainless steel ventilation tube that is curved almost to a right angle, and the mask incorporates an epiglottic elevator at its distal end. Placement of the ILMA results in successful ventilation in almost 100% of cases and successful subsequent intubation in 95%. The ILMA can also be used for ventilation and intubation in obese patients, with similarly high success rates. The ILMA has a special ETT and stabilizer rod to remove the mask over the ETT

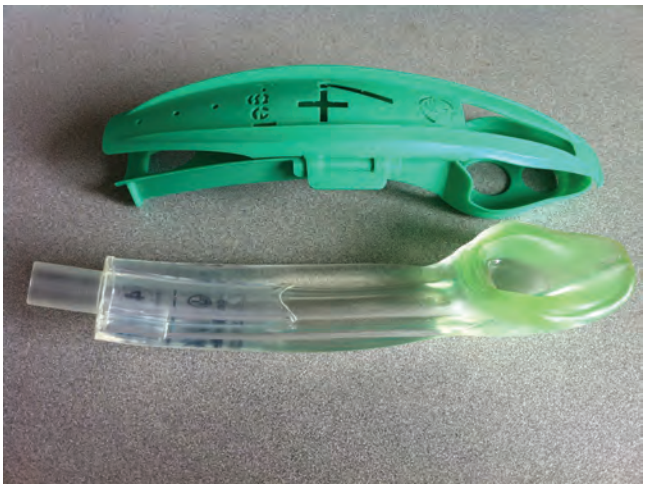

Fig. 1.20. The i-gel mask airway (Intersurgical, Berkshire, England) does not have an inflatable cuff and is available in sizes from infant to adult. (Courtesy Dr. Calvin A. Brown, III.)

Fig. 1.21. The intubating laryngeal mask airway is modified to facilitate insertion of an endotracheal tube after placement and ventilation have been achieved. The epiglottic elevator *(arrowhead)* lifts the epiglottis to allow passage of the special endotracheal tube *(arrow)*.

after intubation has been accomplished, but intubation can be comparably successful with a conventional polyvinylchloride (PVC) ETT.

The ILMA is a better device than the standard LMA for use in the ED because it facilitates rescue ventilation and intubation. Intubation through the ILMA has compared favorably in terms of success with DL and is superior in the hands of novice intubators. When the ILMA is placed, intubation can be performed blindly or guided by a lighted stylet or fiberoptic scope. The ILMA comes only in sizes 3, 4, and 5 and so is not suitable for use in patients weighing less than about 30 kg (≈66 lb). For smaller patients, the standard LMA, which has sizes down to size 1 (infant), should be used. Intubation can be achieved through the standard LMA, but the success rate is significantly less than with the ILMA. As experience with the LMA and ILMA grows, it is likely that there will be increasing adoption of the LMA as a primary airway management technique by nonhospital first responders, and the ILMA has been gaining attention as a primary rescue device in the ED. Newer LMA-style devices, the Ambu air-Q and Aura-I, can act as standard LMAs for ventilation and oxygenation but can facilitate blind intubation with standard adult endotracheal tubes. Both work well intubating a difficult airway, especially when augmented by flexible endoscopy.[51]

In the ED, the primary use of the LMA or ILMA is as a rescue technique to provide a temporary airway when intubation has failed, bag ventilation is satisfactory, and the patient has been paralyzed and may require prolonged ventilation or be in need of immediate airway management. In such cases, the LMA is one of numerous acceptable devices. In the can't intubate, can't ventilate situation, cricothyrotomy is indicated, but an ILMA may be placed rapidly in an attempt to achieve ventilation (converting the situation to can't intubate, can ventilate), as long as this is done in parallel with preparations for cricothyrotomy and does not delay initiation of a surgical airway. The standard LMA may also offer advantages for providing ventilation in unconventional positions, such as when the patient is lying on his or her side. In the out-of-hospital setting, where concerns about esophageal placement of ETTs have focused interest on methods used for airway management, the LMA and Combitube offer excellent placement and ventilation characteristics and may be preferable to endotracheal intubation in this setting, especially when intubation is relatively infrequently performed.[53] If the patient is in a difficult position in terms of intubation access, the LMA may facilitate more rapid ventilation.

Other Extraglottic Devices. In addition to LMAs, which sit above the glottis, there are several other types of EGDs. These are inserted blindly posterior to and beyond the laryngeal inlet to provide oxygenation and ventilation through side ports while inflatable balloons occlude the pharynx above and the esophageal inlet below. Because of their positioning behind the larynx, these often are called retroglottic devices. The prototype for these devices is the esophagotracheal Combitube. The Combitube is a plastic double-lumen tube with one lumen functioning as an airway after esophageal insertion and the other lumen functioning as a tracheal airway. The tube is placed blindly into the esophagus, and proximal and distal balloons are inflated sequentially through different ports. The balloons prevent escape of ventilatory gases upward through the pharynx or downward through the esophagus. The tube is placed into the esophagus, as designed, almost 100% of the time, but both lumens are patent, so ventilation is still possible if the tube has been placed inadvertently into the trachea. It comes in two sizes and is used only in patients taller than 48 inches.

The King laryngeal tube airway (King LT; King Systems) has a single port through which distal and proximal low-pressure balloons are inflated as a single step (Fig. 1.22). The distal balloon, when seated correctly, obstructs the cervical esophagus, and the larger proximal balloon obstructs the hypopharynx, preventing regurgitation of air. A newer version of the King LT has a posterior channel that accepts a nasogastric tube, which can be passed through the device into the stomach for aspiration of gastric contents. The King LT is disposable, rapidly placed, easy to use by operators of various skill levels and has seal pressures similar to those of standard LMAs.[52] All extraglottic devices can be safely left in place for 4 hours without mucosal pressure damage. Another device, the Rusch EasyTube (Teleflex, Morrisville, NC), is similar in concept and appearance to the Combitube but is available in 41 Fr and a smaller 28-Fr size for smaller patients. All retroglottic devices are primarily a substitute for endotracheal intubation for non–ETT-trained personnel, but are also used by advanced airway managers as a way to oxygenate and ventilate patients during crash and failed airway scenarios. These devices should be considered temporary measures, do not protect against aspiration, and should be exchanged for a definitive airway as soon as possible.

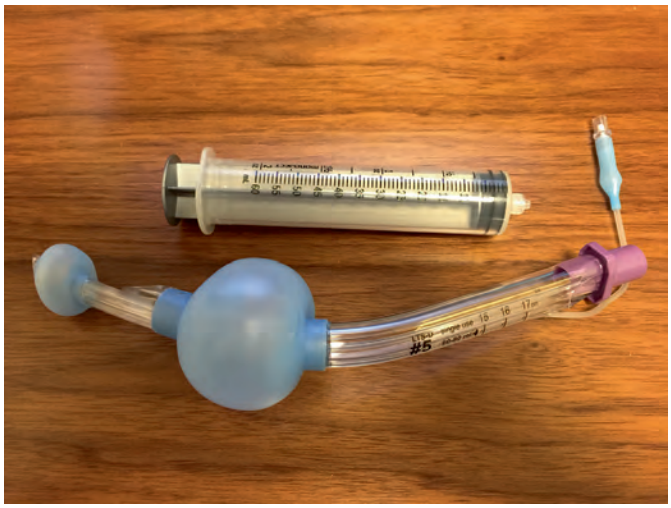

Fig. 1.22. King laryngeal tube incorporates two cuffs but inflates with a single bolus of air. There is a channel in the back for passage of an orogastric tube. It is available in a variety of adult and pediatric sizes.

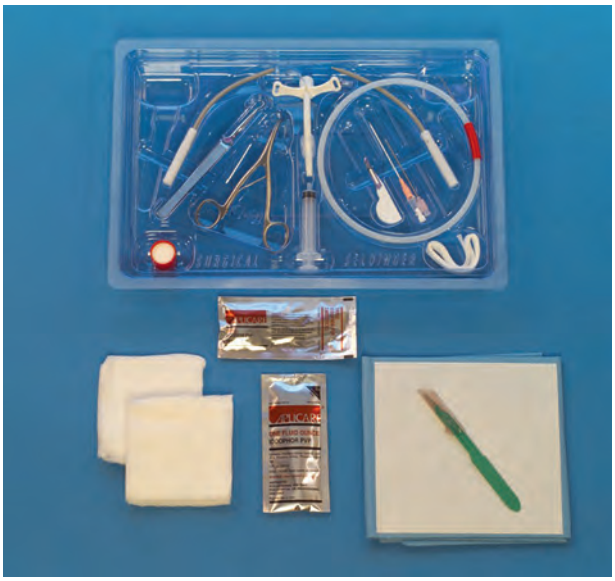

Fig. 1.23. Melker universal cricothyrotomy kit. (Courtesy Cook Critical Care, Bloomington, IN.)

Surgical Airway Management

Needle Cricothyrotomy With Transtracheal Jet Ventilation

With the advent of newer airway devices, especially videolaryngoscopes, surgical airway management, which always has been distinctly uncommon, is required even less frequently.[3] Needle cricothyrotomy, which involves the insertion of a large needle (ideally, a large catheter designed for this purpose) through the cricothyroid membrane into the airway for transtracheal ventilation, may have a limited role in pediatric airway management (see Chapter 161). However, it is rarely, if ever, the right choice for an adult airway emergency and will not be discussed further here.

Cricothyrotomy

Cricothyrotomy is the creation of an opening in the cricothyroid membrane through which a cannula, usually a cuffed tracheostomy tube, is inserted to permit ventilation. The techniques and variations thereof have been well described elsewhere.[53] When surgical airway management is required, cricothyrotomy is the procedure of choice in the emergency setting, where it is faster, more straightforward, and more likely to be successful than tracheotomy.

Cricothyrotomy is indicated when oral or nasal intubation is impossible or fails and when BMV or EGD cannot maintain adequate oxygen saturation (the can't intubate, can't ventilate situation). Previous large series have established that the incidence of cricothyrotomy is approximately 1% of all ED intubations, with the highest rates seen in trauma patients.[16] More recent ED-based intubation surveillance has suggested that the rate of salvage cricothyrotomy—a surgical airway performed after another technique was attempted first—has dropped and is now approximately 0.3%.[3] Cricothyrotomy is relatively contraindicated by distorted neck anatomy, preexisting infection in the neck, and coagulopathy; these contraindications are relative, however, and establishment of the airway takes precedence over all other considerations. The procedure should be avoided in infants and young children, in whom anatomic limitations make it exceedingly difficult. Studies have suggested that approximately five practice cricothyrotomies on a simulator or animal model are sufficient to achieve at least baseline capability with the procedure, although training intervals for skill maintenance have not been well defined.

A number of commercial kits and devices are used to perform percutaneous cricothyrotomy. Percutaneous cricothyrotomy with the Seldinger technique appears comparable to formal open cricothyrotomy in terms of ease of learning and success rates. Patients with clear landmarks are the best candidates for this procedure because patient obesity or altered anatomy may lead to paratracheal tube placement. In patients with indistinct landmarks or for novice operators, standard open cricothyrotomy may be more successful. Bougie-assisted cricothyrotomy, during which a bougie is placed through the cricoid incision and used as a guidewire for ETT placement, may also improve surgical airway success for inexperienced practitioners. The safety and effectiveness of the many cricothyrotomy kits and devices have not been clearly established. Only two percutaneous cricothyrotomy sets currently on the market have the ability to place a cuffed tracheostomy tube. One is a dedicated Seldinger cricothyrotomy set; the other is a combination set that has all necessary equipment for a Seldinger percutaneous cricothyrotomy or standard surgical cricothyrotomy (Melker universal cricothyrotomy kit; Cook Critical Care, Bloomington, IN; Fig. 1.23).

OUTCOMES

Phase II of the National Emergency Airway Registry study (NEAR II) of almost 9000 ED intubations has reported that most patients were intubated by emergency clinicians using RSI, with overall success rates of 96%.[16] The NEAR classification system characterizes potentially adverse occurrences during intubation as adverse events. In the NEAR study, the overall rate of adverse events was 12%, with recognized esophageal or mainstem intubation and hypotension being the most common.[7] Phase III of the NEAR project has reported on more than 17,500 adult ED intubations over an 11-year period (2002–2012).[3] This latest multicenter report has revealed that first-attempt success (FPS) was 83%. However, over the course of data collection, this significantly increased from 80% in the first 3 years to 86% during the last 3 years. Emergency clinicians managed 95% of all patients, and 99% were successfully intubated within three attempts. Adverse event rates (12%) were identical to those of NEAR II, with recognized esophageal intubation and hypotension requiring IV fluids being the most common. The incidence of cricothyrotomy dropped from 0.9% to 0.5%. No studies have evaluated the long-term outcome of intubated ED patients.

KEY CONCEPTS

- Anticipating the clinical course of the patient's condition and assessing the likelihood of deterioration are crucial to the decision to intubate, especially if the patient is to leave the ED for a period of time (eg, interfacility transfer, diagnostic testing).
- Assessment of the patient for potential difficulty with intubation, bag-mask ventilation (BMV), ventilation using an extraglottic device (EGD), and cricothyrotomy is an essential step before a neuromuscular blockers is administered. The mnemonics *LEMON, MOANS, RODS* and *SMART* can serve as useful aids.
- In the absence of a crash patient (agonal, unresponsive to laryngoscopy) or difficult airway, rapid sequence intubation (RSI) is the airway management method of choice for ED patients.
- Tube placement confirmation using end-tidal CO_2 ($ETCO_2$) is essential after intubation; failure to detect adequate quantities of exhaled CO_2 is evidence of esophageal intubation until proven otherwise.
- Videolaryngoscopy has transformed intubation by eliminating many of the traditional anatomic barriers to direct laryngoscopy. Practitioners responsible for emergency airway management should transition their routine airway management from direct laryngoscopy to videolaryngoscopy.
- Cricothyrotomy is indicated in the can't intubate, can't oxygenate failed airway situation and should be performed without hesitation once this has been identified. Delays may increase the likelihood or severity of hypoxic injury to the patient.
- Emergency airway management is evolving, and modern intubators should be aware of these fundamental changes. Videolaryngoscopy is replacing direct laryngoscopy as the tool of choice for emergency airway management. Etomidate is used in more than 90% of all RSIs, and rocuronium use has been increasing. EGDs, such as laryngeal mask airways, are continually evolving, offering additional options for rescue oxygenation of the failed airway.

The references for this chapter can be found online by accessing the accompanying Expert Consult website.

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CHAPTER 1: QUESTIONS & ANSWERS

1.1. Which of the following is considered unreliable for assessing the need to establish an artificial airway?
A. Absence of a gag reflex
B. Absence of swallowing on command
C. Level of consciousness
D. Patient's ability to phonate
E. Pooling of secretions in the oropharynx

Answer: A. The gag reflex can be absent in up to 25% of normal adults. Moreover, there is no evidence that the presence or absence of a gag reflex corresponds to a patient's ability to protect his or her airway. It should therefore not be used as an indicator of the need for intubation.

1.2. Which of the following is the most reliable overall method for confirmation of correct tube placement after endotracheal intubation?
A. Bulb aspiration
B. Chest and gastric auscultation
C. Chest radiography
D. Detection of colorimetric or quantitative end-tidal carbon dioxide ($ETCO_2$)
E. Measurement of exhaled volume

Answer: D. Detection of $ETCO_2$ after endotracheal intubation is the most reliable of the options listed for the confirmation of tube placement. (A fiberoptic scope passed through the endotracheal tube, with visualization of the tracheal rings, is the gold standard but is not generally required.) Limitations of colorimetric CO_2 detection should be appreciated in cardiac arrest patients. In these situations, a bulb aspiration device may provide helpful information, even though this technique is generally not as reliable as $ETCO_2$ detectors. The other listed options, traditional as they may be, are prone to failure and should not be relied on for confirmation of tube placement.

1.3. During rapid sequence intubation (RSI), what is the optimal time to wait between the administration of a pretreatment drug and administration of the induction agent and neuromuscular blocking agent?
A. 1 minute
B. 2 minutes
C. 3 minutes
D. 4 minutes
E. 5 minutes

Answer: C. Three minutes is considered the optimal time to wait between the administration of a pretreatment drug and administration of the induction agent. If the clinical situation does not allow for this length of time between administrations, there may still be some benefit to administration of the pretreatment agent.

1.4. In which of the following conditions is succinylcholine contraindicated?
A. Acute burn < 5 days
B. Acute head injury secondary to motor vehicle accident
C. Acute spinal cord injury < 5 days
D. Renal failure with a serum potassium level of 4.7 mEq/L
E. Stable multiple sclerosis

Answer: E. Succinylcholine has been associated with severe fatal hyperkalemia when administered in specific clinical circumstances. The risk of succinylcholine-induced hyperkalemia in patients with denervation syndromes begins with the onset of disease and continues indefinitely. With respect to acute burns, trauma, stroke, spinal cord injury, and intraabdominal sepsis, the risk of hyperkalemia with succinylcholine use becomes evident 5 days after the onset of injury or disease process. Succinylcholine is not contraindicated in renal failure; however, known elevations in the potassium level may warrant use of another neuromuscular blocking agent.

1.5. Which of the following conditions prevents reliable use of colorimetric capnometers for the detection of esophageal intubation in 25% to 40% of cases?
A. Acute asthma exacerbation
B. Cardiac arrest
C. Chronic obstructive pulmonary disease exacerbation
D. Head trauma
E. Pneumonia

Answer: B. Colorimetric capnometers detect CO_2 and can be used to confirm tracheal intubation. The absence of CO_2 detection indicates failure to intubate the trachea and necessitates reintubation, except in the low-perfusion state of cardiac arrest, when quantities of CO_2 returned to the lungs may be insufficient to produce a color change in the capnometer. This situation occurs in 25% to 40% of intubated cardiac arrest patients. The placement of the tube needs to be confirmed by clinical means, revisualizing placement, or the tube needs to be removed and the patient reintubated.

1.6. Until how long after an acute burn is succinylcholine considered safe to use for RSI?
A. 30 minutes
B. 12 hours
C. 24 hours
D. 48 hours
E. 5 days

Answer: E. Succinylcholine can produce severe (and fatal) elevations in serum potassium levels after administration in patients with burns. However, this vulnerability to succinylcholine-induced hyperkalemia is not clinically significant until at least 5 days after the acute burn. As a result, succinylcholine remains the paralytic of choice if rapid sequence intubation occurs less than 5 days after the burn.

CHAPTER 2

Mechanical Ventilation and Noninvasive Ventilatory Support

Todd A. Seigel

PERSPECTIVE

Invasive and noninvasive ventilation are essential components in the management of critically ill patients. Some patients require support for respiratory failure or as part of comprehensive management of critical illness, whereas other patients require assistance primarily for airway protection. The reasons for initiating ventilatory support are varied and will influence ventilation strategy, hemodynamics, sedation strategy, and subsequent clinical course.

The decision to intubate is discussed in Chapter 1 and in other chapters throughout this text in the context of individual conditions. This chapter describes the modalities and techniques of noninvasive and invasive mechanical ventilation.

PRINCIPLES OF MECHANICAL VENTILATION

Physiology of Positive-Pressure Breathing

Spontaneous breathing in normal patients is based on the initiation of negative intrathoracic pressure. It is mediated by contraction and relaxation of the diaphragm in concert with the intercostal muscles. Contraction of the diaphragm and intercostal muscles increases the intrathoracic volume, creating negative pressure in the chest cavity and causing inhalation, whereas relaxation of the diaphragm and recoil of the chest wall decreases intrathoracic volume, which increases pressure in the chest cavity and results in passive exhalation. The amount of force required to generate adequate inspiration is influenced by the work of breathing; when the work of breathing increases, patients may be unable to generate enough negative force to sustain successful respiration and will require ventilatory support. Unlike spontaneous breathing, invasive and noninvasive mechanical ventilation are based on the delivery of humidified air with positive pressure. The amount of positive pressure required for adequate ventilation is dependent on the patient's respiratory effort, ranging from mild assistance to full support. Inhalation occurs by driving air into the lungs under positive pressure; air is passively exhaled when the chest wall recoils.

Transition from negative-pressure breathing to positive-pressure breathing affects cardiovascular and pulmonary physiology and can have significant clinical consequences. Pressure changes in the thoracic cavity directly affect pressures in the chambers of the heart. During spontaneous inspiration, decreased intrathoracic pressure augments venous return and preload. Cardiac output is increased, and there is an increased pressure gradient between the left ventricle and aorta. With the initiation of positive-pressure ventilation (PPV), the opposite occurs—venous return is diminished, cardiac output falls, and there is a decreased pressure gradient between the left ventricle and aorta. Relative hypotension can occur after ventilatory support has been initiated, and this may be exaggerated in patients with clinical hypovolemia or vasodilatory states.

Invasive Mechanical Ventilation: Control Variable and Ventilator Mode

The primary considerations regarding initiation of mechanical ventilation relate to how each breath should be delivered. This includes how a breath is defined, the size, duration, and frequency of the breath, and the degree of interaction the patient has with the ventilator.

How the ventilator defines a breath is referred to as the control variable. The ventilator can give breaths based on delivery of a set pressure or a set volume, referred to as pressure-controlled ventilation (PCV) and volume-controlled ventilation (VCV), respectively. The amount of time over which the breath is delivered is defined as the inspiratory time, and the speed at which air travels through the circuit is defined as inspiratory flow rate.

In PCV, a set amount of pressure is applied to the airway to expand the lungs for a specified amount of time. During PCV, the target pressure and inspiratory time are set by the provider, whereas the delivered tidal volume and inspiratory flow rate vary as functions of dynamic lung compliance and airway resistance. Ability to control the pressure delivered to the lungs is particularly useful to prevent barotrauma, which is described in more detail below. In addition, because inspiratory flow is not fixed, PCV may improve ventilator synchrony in intubated patients with a high respiratory drive. A significant disadvantage of PCV is that as tidal volume changes with acute changes in lung compliance, it can neither be guaranteed nor limited. PCV offers advantages over VCV in clinical conditions in which control of airway pressure is strictly mandated. This includes patients with the potential to develop dynamic hyperinflation and intrinsic positive end-expiratory pressure (PEEP) such as patients with severe asthma or respiratory failure from chronic obstructive pulmonary disease (COPD).

In VCV, a breath is defined by delivery of a set tidal volume to the lungs. Inspiratory volume and flow rate are set by the provider, and inhalation ends once a preset tidal volume has been delivered. The inspiratory time is a function of the set flow rate. Lung pressure—peak inspiratory pressures (PIPs) and end-inspiratory alveolar pressures—vary based on lung compliance and set tidal volume. The main benefit to the use of VCV is the ability to control tidal volume and minute ventilation, but VCV may cause spikes in peak pressures when compliance of the respiratory system is poor. Clinically, poor respiratory system compliance occurs in conditions that increase lung or chest wall stiffness, including pulmonary edema, acute respiratory distress syndrome (ARDS), pneumothorax, and obesity.

The choice between pressure-cycled ventilation and volume-cycled ventilation is driven by the underlying indication for mechanical ventilation. Volume-cycled ventilation should be used when strict control of tidal volume is mandated. Specifically, this includes patients with known ARDS, in whom low tidal volume strategies have been proven to reduce mortality. In addition,

TABLE 2.1

Features of Pressure Control Versus Volume Control

	SET PARAMETERS	VARIABLE PARAMETERS	CLINICAL IMPLICATIONS	CLINICAL CONDITIONS
Pressure-controlled ventilation (PCV)	Pressure target, inspiratory time, RR, PEEP	Tidal volume, inspiratory flow rate	Controls airway pressure, but tidal volume becomes a function of lung compliance (no guaranteed tidal volume or minute ventilation). Allows estimation of end-inspiratory alveolar pressure based on ventilator settings. Variable inspiratory flow helpful for patients with high respiratory drive	Severe asthma COPD, salicylate toxicity
Volume-controlled ventilation (VCV)	Tidal volume, RR, inspiratory flow pattern, inspiratory time	PIP, end-inspiratory alveolar pressure	Guaranteed delivery of tidal volume, but may result in high or injurious lung pressures. End-inspiratory alveolar pressure cannot be reliably estimated and must be measured (plateau pressure)	ARDS, obesity, severe burns

ARDS, Acute respiratory distress syndrome; *COPD,* chronic obstructive pulmonary disease; *PIP,* peak inspiratory pressure; *PEEP,* positive end-expiratory pressure; *RR,* respiratory rate.

patients with decreased chest wall compliance should be placed on VCV to ensure that adequate tidal volume is delivered. This includes patients with morbid obesity or severe chest wall burns. Conversely, in conditions in which strict control of airway pressure is desired, pressure-cycled ventilation should be used. As detailed earlier, this occurs most often in patients with asthma or COPD. In addition, because inspiratory flow is not limited in pressure-cycled ventilation, this strategy may be preferred to volume-cycled ventilation in patients with a high respiratory drive such as patients with salicylate overdose. For patients who do not require strict control of pressure or volume, similar ventilation mechanics can generally be achieved with pressure-cycled or volume-cycled ventilation (Table 2.1).

Newer ventilators can deliver breaths that combine volume and pressure strategies, referred to as dual-control ventilation. A common dual-control method of ventilation is pressure-regulated volume control (PRVC). A variation of volume control, PRVC is set to deliver a specific tidal volume while simultaneously minimizing airway pressure. Unlike with strict volume control, pressure is measured and modulated by the ventilator with each breath to ensure the delivery of the preset tidal volume. In addition, a pressure limit is set, and the ventilator sounds an alarm when that pressure has been exceeded. Theoretically, this combines the advantages of pressure and volume control to ensure the delivery of a specific tidal volume while the airway pressure is monitored. That said, because the ventilator is set to deliver a specific tidal volume, the disadvantages of volume-cycled ventilation persist. In addition, elevations in airway pressure are still possible and must be addressed if acute changes in respiratory system compliance occur. This mode of ventilation has not been specifically studied but likely does not offer significant advantage over traditional volume- or pressure-cycled ventilation, particularly if strict parameters for airway pressure are desired.

The term *ventilator mode* refers specifically to the amount of respiratory support provided by the ventilator. The most common ventilator modes can be categorized on the basis of how often the ventilator will initiate a breath for the patient and can be divided broadly into continuous mechanical ventilation (CMV), intermittent mechanical ventilation (IMV), and continuous spontaneous ventilation (CSV). CMV and IMV are intended to provide patients with a specific minimum number of preset breaths as defined by the ventilator and can be delivered via pressure or volume control methods. Conversely, in CSV, no mandatory breaths are delivered to a patient; the size and rate of the breaths are determined by the effort of the patient and are augmented with applied pressure to the airway. These methods are compared in Table 2.2. Other, more complex modes of ventilation include proportional assist ventilation (PAV) and airway pressure release ventilation (APRV), although these generally are not used in the emergency department (ED).

CMV is intended to provide full ventilatory support for patients with little or no spontaneous respiratory activity continuous delivery of preset breaths. However, if a patient generates negative pressure, representing respiratory effort, on CMV, that breath will be assisted by the ventilator. For this reason, CMV is also referred to as assist-control (A/C) ventilation. In this mode, patients can trigger a breath at any rate but will always receive at least the preset number of breaths. Notably, when a patient initiates a breath, the assisted breath that he or she receives is the full volume breath as set on the ventilator. For the promotion of ventilator synchrony, a spontaneous patient-initiated breath will take priority over a preset breath, meaning that if the ventilator is set to deliver 12 breaths/min, a breath is provided every 5 seconds in the absence of spontaneous inspiratory effort. When the patient makes a spontaneous effort, the ventilator provides an additional breath and the timer resets for another 5 seconds. A/C ventilation is the most useful initial mode of mechanical ventilation in ED patients, because many patients are initially paralyzed and sedated and do not interact with the ventilator. One of the biggest challenges with A/C ventilation, however, is that patient-initiated breaths are not proportional to patient effort; when inspiratory effort is detected, a full-sized breath is delivered. Clinically, this requires adequate sedation of patients when ventilated in the A/C mode to prevent spontaneous respiratory efforts that will result in hyperventilation, air trapping, hypotension, and poor ventilator synchrony.[1]

Synchronized intermittent mandatory ventilation (SIMV) provides intermittent ventilatory support to patients by delivering mandatory and spontaneous breaths. In SIMV, a mandatory breath is given at a preset rate, but the breath is synchronized as much as possible with spontaneous patient effort. Similar to A/C, the patient will receive at least the minimum number of preset mandatory breaths; if the patient provides no effort, the preset number of breaths will be given. If a patient has a rate of spontaneous respirations lower than the set rate, the ventilator will provide the preset number of full breaths but will deliver as many as possible in synchrony with patient effort. In these scenarios, there is little difference between A/C and SIMV. If a patient has a rate of spontaneous respirations higher than the preset rate, the patient receives all preset full breaths at the set rate, but additional