Challenges and Advances in Intubation: Airway Evaluation and Controversies with Intubation

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THE DIFFICULT/FAILED AIRWAY

The failed airway has been defined as three failed attempts at orotracheal intubation by a skilled practitioner or failure to maintain acceptable oxygen saturations, typically 90% or above in otherwise normal individuals.\textsuperscript{1} A failed intubation is when “placement of the endotracheal tube fails after multiple intubation attempts.”\textsuperscript{2}

A difficult airway is present whenever there is difficulty in performing any of the following: bag valve mask (BVM) ventilation, laryngoscopy and intubation, or surgical airway techniques (eg, cricothyrotomy).\textsuperscript{1,2} Some experts also include difficulty in placement of extraglottic devices. The American Society of Anesthesiologists (ASA) also defines a difficult airway as (1) difficult BVM ventilation—the inability to maintain an adequate oxygen saturation greater than 90% or signs of inadequate ventilation (eg, cyanosis, absent breath sounds, or hemodynamic instability) with BVM ventilation\textsuperscript{2} or (2) difficult endotracheal intubation—greater than three failed intubation attempts or failure to intubate after 10 minutes by an experienced operator.\textsuperscript{3}

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\textbf{KEYWORDS}

- Intubation
- Endotracheal intubation
- Airway evaluation
EVALUATION OF THE AIRWAY

In emergency medicine (EM), patients in need of a definitive airway (eg, an endotracheal tube), can be categorized into two groups: (1) those who need immediate airway as soon as possible, often referred to as a crash airway, and (2) those in need of an urgent airway. Those patients in need of an immediate airway, the crash airway, generally belong to the category of nearly dead or newly dead, and immediate action is taken to intervene in and secure a definitive airway by any means possible. Patients in the second group may be evaluated (as with anyone needing an elective airway) for the possibility of a difficult airway.

**Difficult Bag Valve Mask Ventilation**

Various anatomic features associated with difficult BVM ventilation are summarized by the mnemonic, MOANS (Box 1). MOANS refers to Mask seal, Obese, Aged, No teeth, and Snore or Stiff. Any condition that causes an inadequate seal of the mask on the face, such as facial discontinuity (as with facial trauma, including facial fractures),

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<tr>
<td>M = Mask seal: facial anatomic deformities, including traumatic facial injuries, or beards</td>
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<tr>
<td>O = Obese: also includes parturient women and patients who have upper airway obstruction</td>
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<tr>
<td>A = Aged (&gt;55 years)</td>
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<tr>
<td>N = No teeth</td>
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<td>S = Snore or Stiff</td>
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<td><strong>Difficult extraglottic device: RODS</strong></td>
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<tr>
<td>R = Restricted mouth opening</td>
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<tr>
<td>O = Upper airway obstruction at the level of the larynx or below</td>
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<tr>
<td>D = Disrupted or distorted</td>
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<tr>
<td>S = Stiff lungs or cervical spine</td>
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<td><strong>Difficult cricothyrotomy: SHORT</strong></td>
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<tr>
<td>S = Surgery/disrupted airway</td>
<td></td>
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<tr>
<td>H = Hematoma or infection</td>
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<tr>
<td>O = Obese/access problem</td>
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<tr>
<td>R = Radiation</td>
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<td>T = Tumor</td>
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<td><strong>Difficult laryngoscopy and intubation: LEMON</strong></td>
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<td>L = Look externally</td>
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<td>E = Evaluate 3-3-2</td>
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<tr>
<td>M = Mallampati class</td>
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<td>O = Obstruction</td>
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<td>N = Neck mobility</td>
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a beard, fluids/materials (eg, blood, emesis, or secretions), or facial anomalies (Pierre Robin syndrome, micrognathia and so forth), can lead to a poor mask seal and poor BVM ventilation (M). Although some clinicians suggest use of a viscous substance, such as petroleum jelly or K-Y jelly, to help create a better mask seal to the face, other experts believe this is counterproductive in that it makes the entire face too slippery to hold the mask in place.4

BVM frequently is difficult in obese (O) patients. Other patients who are especially difficult to ventilate by bag and mask include parturient women and anyone who has upper airway obstruction (O) from an infectious cause (including epiglottitis, retropharyngeal abscess, peritonsillar abscess, croup, or Ludwig’s angina) or a noninfectious case (angioedema, allergy, hematoma, foreign body, malignancy, tumor, and so forth). Care also should be taken not to create any iatrogenic airway obstruction or turn a partial into complete obstruction by positioning or airway procedures or manipulations or by medications.

The aged (A), in this definition age greater than 55 years, are believed more difficult to bag and mask ventilate because of a loss of upper airway muscle and tissue tone.

Edentulous (N, No teeth) patients, because the face caves in, may be difficult for BVM ventilation. Ideally, clinicians may leave dentures in situ while BVM ventilation is occurring and then remove them when intubating. Although some have suggested putting gauze into the cheeks to puff them out to obtain a better mask seal, the danger of possible dislodgement of the gauze into the airway makes this a less than ideal option.

The S in MOANS refers to snores with a need to check for sleep apnea and for stiffness of the lungs, which can occur in diseases with increased airway resistance (such as asthma) or increased pulmonary compliance (for example, pulmonary edema, heart failure, or pneumonia).

Difficult Insertion of Extraglottic Devices

In an emergency, a laryngeal mask airway (LMA) can serve as the primary rescue airway in a cannot ventilate/cannot intubate scenario or can be used as a bridge or temporary airway while completing a cricothyrotomy.2 The LMA also is used routinely in many nonemergency settings, including operating rooms (ORs), for elective cases.

The LMA is inserted above the glottis into the laryngeal space and then a cuff is inflated to achieve the proper seal. This directs air from above the vocal cords through the glottis into the trachea. A proper seal is essential to create a channel through which oxygen is routed into the trachea. The LMA and Combitube are mentioned in the 2003 ASA difficult airway algorithm.2 The LMA and Combitube are considered intermediate airways.

An intermediate airway refers to the use of devices that allow ventilation across the larynx but do not provide complete airway control.5 They are in-between or intermediate between a patent airway and definitive airway control as with endotracheal intubation. Intermediate airway devices do not allow for complete airway control. They generally involve blind placement. There are many different intermediate airways. Examples of such devices include the esophageal obturator airway (EOA), esophageal gastric tube airway (EGTA), esophageal-tracheal Combitube airway, laryngotracheal airway, laryngeal airway, airway management device, cuffed oropharyngeal airway, and laryngeal mask airway (LMA). Some of these devices are placed into the esophagus (EOA and EGTA); others may be placed into the esophagus or the trachea (esophageal-tracheal Combitube); and others are inserted into the airway above the glottis (LMA). Because of the complications associated with the EOA and the EGTA and other recent advances in airway management, there has been a marked decrease
in EOA/EGTA use. The terms, extraglottic and supraglottic devices, also have been used to describe those intermediate airway devices that do not enter the esophagus or trachea but are placed above the glottis for the purpose of ventilation. The LMA is the prototype of the extraglottic or supraglottic devices.

The mnemonic, RODS, is used to predict difficult insertion of extraglottic devices (see Box 1). At least some access to the oral airway is necessary for placement of an extraglottic device, so the R in RODS stands for restricted mouth opening. An extraglottic device is not feasible if there is upper airway obstruction (O). A disrupted or distorted airway (D) prevents an adequate seal, thereby resulting in unsatisfactory functioning of the extraglottic device. A stiff cervical spine or stiff lungs are the S in RODS. A proper seal in the supraglottic airway is difficult or impossible when there is a flexion deformity of the neck. A marked increase in airway resistance (as occurs in status asthmaticus) or severely decreased pulmonary compliance (for example, pulmonary edema) leads to stiff lungs.

**Difficult Cricothyrotomy**

There are three absolute contraindications to surgical cricothyrotomy: (1) endotracheal intubation can be accomplished easily and quickly and no contraindications to endotracheal intubation are present, (2) tracheal transection with retraction of the distal end into the mediastinum, and (3) a fractured larynx or significant damage to the cricoid cartilage or larynx. The relative contraindications to surgical cricothyrotomy are acute laryngeal disease, a bleeding diathesis, age less than 5 to 12 years (transtracheal ventilation is preferred instead of surgical cricothyrotomy in infants and young children), and massive neck edema (a modified technique can be used).

The mnemonic, SHORT, has been used to determine clinical characteristics that presage a difficult cricothyrotomy (see Box 1). The S represents Surgery/disrupted airway. Any anatomic distortion, from prior surgery, trauma, congenital anomalies, or disease states, probably makes airway access and cricothyrotomy more difficult. H stands for hematoma, bleeding, or infection in the surgical area that complicates the procedure. Obese/access is the O in SHORT and represents any situation that impairs access to the cricothyroid membrane. Prior Radiation (R) to this region of the neck may cause scarring and tissue distortion and T is for Tumor in the area that may cause bleeding and distort the anatomy. Any of these conditions makes it more difficult to perform a surgical cricothyrotomy.

**Difficult Laryngoscopy and Intubation**

During general anesthesia, the incidence of difficult tracheal intubation has been estimated at 3% to 18% in one report and from 1.5% to 8.5% in another study compared with a 0.13% to 0.3% incidence of failed intubation. The usual estimate for difficult intubation in anesthetic practice is cited as 1% to 3%. The Australian Incident Monitoring Study reported a 4% (160/4000 patients) incidence of problems with intubation and a 0.025% (5/2000) incidence of emergency transtracheal airway. Various techniques or scales have been devised to predict difficult intubation in a given patient.

**Visualization of the Glottis**

An inadequate view of the glottis presumes difficult laryngoscopy and intubation.

**Cormack Grades of Visualization of Glottis**

The traditional method for assessing the degree of visualization of the glottis is the Cormack (Cormack-Lehane) laryngeal view grade score. The grades of difficulty in
laryngoscopy are grade 1, full view of vocal cords/glottis; grade 2, partial view of vocal cords/glottis; grade 3, only epiglottis seen; and grade 4, no exposure of glottis, epiglottitis cannot be seen. Grades 3 and 4 imply difficult laryngoscopy (see Box 1; Fig. 1).

Percent of Glottic Opening

Other scoring systems exist that grade the percent of glottic opening (POGO) (see Box 1; Fig. 2). Although POGO allows differentiation between the ranges of partial glottic visibility from small to large, the Cormack grading system is still more widely used.

VISUALIZATION OF THE UPPER AIRWAY: MALLAMPATI CLASS

The ability to visualize the poster oropharyngeal structures affects the success of laryngoscopic intubation. The better the view, the more likely the intubation is successful.

The Mallampati class frequently is used to evaluate for the possibility of a difficult intubation. It originally was devised as a part of a preoperative evaluation before a controlled intubation in an OR. It is done by having a patient sit on the edge of a table or bed and lean slightly forward; then an examiner asks the patient to open his or her mouth as widely as possible without talking or vocalizing. A Mallampati class then is given based on the extent to which the base of the uvula, soft palate, and faucial pillars can be visualized. The Mallampati score, as modified by Samsoon and Young, is grade I, faucial pillars, soft palate, and uvula visualized; grade II, faucial pillars and soft palate visualized but uvula masked by base of the tongue; grade III, only soft palate visualized; and grade IV, soft palate not seen (see Box 1; Fig. 3). Mallampati classes I and II are associated with low intubation failure rates, whereas difficult intubation is more likely with Mallampati classes III and IV. With Mallampati class IV intubation, failure rates are greater than 10%.

EXTERNAL EVALUATION OF THE AIRWAY

Patil’s Triangle

The thyromental distance or thyromental line has been cited as a predictor of a difficult airway. If the thyromental distance is less than 6 cm, intubation may be impossible, and if greater than 6.5 cm conventional laryngoscopy usually is possible. The thyromental line is the distance between the upper border of the thyroid cartilage (e.g., superior thyroid notch or Adam’s apple) to the tip of the jaw or mental

**Fig. 1.** Cormack (Cormack-Lehane) grades of visualization of glottis. Grade 1, full view of glottis, vocal cords visible; grade 2, vocal cords partly visible, only posterior aspect of glottis visible (posterior commissure view); grade 3, glottis not visible, only epiglottis is seen; and grade 4, glottis, vocal cords, and epiglottis are not visible. (Courtesy of Sharon E. Mace, MD, and Beth Halasz of the Cleveland Clinic Center for Medical Art and Photography, Cleveland, OH; with permission.)
protuberance of the chin with the head extended. The thyromental line also is the hypotenuse of a right angle triangle, Patil’s triangle, used to describe the anatomic relationships (see Fig. 3).\(^4,16\) The axis of Patil’s triangle is the length of the mandible or the floor of the mouth, which is a measure of the mandibular space. The abscissa of Patil’s triangle is the distance between the base of the mandible and the top of the larynx and determines the position of the larynx with respect to the length of the mandible or the floor of the mouth. The length of the oral axis, which is the axis of Patil’s triangle or the second of the 3-3-2 evaluation, is important because it affects the ability to expose the glottis during laryngoscopy. With a very short oral axis, the larynx is covered by the base of the tongue which prevents visualization of the glottis, whereas an excessively long oral axis places the glottis beyond the horizon of visibility (Box 2; Fig. 4).

### 3-3-2 Assessment

The 3-3-2 assessment evaluates the degree of mouth opening and mandible size in relation to the position of the larynx in the neck as elements affecting the likelihood of a successful intubation (Fig. 5). The initial 3 represents the degree of oral access. A patient’s mouth should be able to be opened at least three fingerbreadths (approximately 5 cm) between upper and lower teeth (see Fig. 5A).

The second 3 refers to the distance between the protuberance of the chin or mentum and the hyoid bone, which should allow three fingerbreadths (approximately 5 cm) along the floor of the mandible between the mentum and the mandible/neck junction, near the hyoid bone. The second 3 is an index of the mandibular space’s ability to be large enough to have capacity for the tongue during laryngoscopy. Three fingerbreadths is ideal. Otherwise, if the mandibular space is too small (eg, <3 fingerbreadths), the mandibular space cannot accommodate the tongue, thereby obscuring the view of the glottis. Conversely, if the mandibular space is too large (eg, >3 fingerbreadths) then the elongated oral axis may impair visualization of the glottis (see Fig. 5B).

The 2 of the 3-3-2 refers to the position of the larynx in relation to the base of the tongue (see Fig. 5C). Two fingerbreadths between the hyoid bone and the upper anterior edge of the thyroid cartilage (superior laryngeal notch) is ideal. Greater than two fingerbreadths signifies the larynx is located further beyond the base of the tongue.
and, therefore, may be positioned so far down the neck that it is beyond the visual horizon during laryngoscopy. Less than two fingerbreadths suggests an anterior larynx with the larynx located up under the base of the tongue, making it difficult to expose. Inability to attain the 3-3-2 rule implies that it will be difficult or impossible to line up the three axes (oral, pharyngeal, and tracheal axes) for intubation, thereby making intubation difficult or impossible (Fig. 6).

OVERALL ASSESSMENT

Another mnemonic, LEMON, has been used as an aid to recognizing risks for difficult intubation\(^1\) (see Box 1). The rule of thumb is, if it looks difficult, it probably is. \(L\) stands for Look externally. Anatomic features indicative of a likely difficult or failed intubation can be secondary to trauma or nontraumatic conditions/illnesses, which may be congenital or acquired (Box 3).

Evaluating 3-3-2 is the \(E\) in LEMON. The \(M\) of the LEMON refers to the Mallampati class. Obstruction is the \(O\) in the LEMON mnemonic. Anytime upper airway obstruction (partial or complete) is present, a difficult airway also is present. Even a small dose of a sedative or opioid (sometimes administered to relieve anxiety) relaxes the upper airway muscle tone, which can turn a partial obstruction into complete airway obstruction.

**Fig. 3.** Mallampati Class. Class I: soft palate, uvula and pillars visible; class II: soft palate and uvula visible; class III: soft palate and only base of uvula visible; and class IV: faucial pillars, soft palate, and uvula not visible (only hard palate visible). (Courtesy of Sharon E. Mace, MD, and Beth Halasz of the Cleveland Clinic Center for Medical Art and Photography, Cleveland, OH; with permission.)
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<td><strong>Visualization of glottis</strong></td>
<td>Cormack laryngeal view score</td>
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<td>Grade 1: Full view of glottis and vocal cords</td>
<td>Grade 2: Vocal cords and glottis are partly visible</td>
</tr>
<tr>
<td>Grade 3: Only epiglottis seen, glottis is not visible</td>
<td>Grade 4: No exposure of glottis, the glottis and epiglottis are not visible</td>
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<td><strong>Percent of glottic opening</strong></td>
<td><strong>Visualization of upper airway</strong></td>
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<td><strong>Mallampati class</strong></td>
<td><strong>Class I:</strong> Faucial pillars, soft palate, and uvula visualized</td>
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<tr>
<td><strong>Class II:</strong> Faucial pillars and soft palate visualized, uvula not seen (masked by tongue)</td>
<td><strong>Class III:</strong> Only soft palate visualized</td>
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<tr>
<td><strong>Class IV:</strong> Faucial pillars, soft palate, and uvula not visualized (only hard palate visualized)</td>
<td><strong>External evaluation of the airway</strong></td>
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<td><strong>Patil’s triangle</strong></td>
<td>Hypotenuse: thyromental line equals distance between the protuberance of the chin (mentum) and the angle of the superior thyroid notch (Adam's apple) (eg, upper border of the thyroid cartilage)</td>
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<tr>
<td>Axis: distance between the protuberance of the chin (mentum) and the angle of the mandible equals length of the mandible, measures mandibular space or floor of the mouth</td>
<td>Abscissa: distance between the angle of the superior thyroid notch and the base of the mandible</td>
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<td><strong>Overall evaluation</strong></td>
<td><strong>Intubation difficulty scale</strong></td>
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<tr>
<td><strong>N1:</strong> Number of supplementary attempts at endotracheal intubation</td>
<td><strong>N2:</strong> Number of supplementary additional operators</td>
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<td><strong>N3:</strong> Number of alternative techniques used</td>
<td><strong>N4:</strong> Cormack grade minus 1 (eg, N4 = 0, with Cormack grade = 1)</td>
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<td><strong>N5:</strong> Lifting force applied during laryngoscopy (N5 = 0 little effort, N5 = 1 increased effect)</td>
<td><strong>N6:</strong> Is external laryngeal manipulation required (N6 = 0 no, N6 = 1 yes)</td>
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<td><strong>N7:</strong> Position of vocal cords (N7 = 0 abduction, N7 = 1 abduction)</td>
<td><strong>Elements for best attempt at conventional laryngoscopy</strong></td>
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<td>Performance by a reasonably experienced practitioner</td>
<td>No significant muscle tone</td>
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<td>Optimal &quot;sniffing&quot; position</td>
<td>Blade length</td>
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<tr>
<td>Blade type</td>
<td>Use of laryngeal manipulation</td>
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Neck mobility is the N component of LEMON. Positioning the head and neck in the sniffing position to obtain the best view of the glottis is considered one of the key elements in successful laryngoscopic intubation (see Fig. 6). Inability to do so for any reason, including cervical spine immobilization in a trauma patient, makes intubation more difficult.

SPECIFIC VARIABLES ASSOCIATED WITH FAILED/DIFFICULT AIRWAY

Specific conditions/injuries associated with a difficult or failed airway are listed in Box 3. Obesity, limited neck mobility, and mouth opening are the most frequently noted anatomic features leading to difficult intubation or a failed airway according to a review of more than 4000 patients in the Australian Incident Monitoring Study.9

Variables associated with a difficult or failed airway according to some experts include interincisor distance less than or equal to 3 cm, thyromental distance less than or equal to 6 cm, maxillary dentition interfering with jaw thrust, Mallampati class IV, neck in fixed flexion, and extreme head or neck changes secondary to masses, scarring, radiation, and so forth.15 Other elements that are associated with a difficult or failed airway in some reports (but not in other studies) are increased age, male gender, obstructive sleep apnea, high body mass index, and pretracheal soft tissue.15

There have been other attempts to predict difficult intubation. The combination of a high modified Mallampati class and a thyromental distance less than 7 cm has been suggested as a predictor of a difficult intubation.17 The triad of decreased atlanto-occipital extension, decreased mandibular space, and increased tongue thickness presages a difficult intubation according to a retrospective radiographic study.18
Another study using mouth opening, chin protrusion, and atlanto-occipital extension had 86.8% sensitivity and 96% sensitivity in predicting difficult intubation.\textsuperscript{19}

**Intubation Difficulty Scale**

The intubation difficulty scale (IDS), suggested by the ASA in 1997, uses seven variables to grade an intubation.\textsuperscript{20}

Higher scores are significantly correlated with longer intubation times and an operator’s subjective rating of intubation difficulty. The seven IDS variables are N1, number of supplementary attempts at endotracheal intubation; N2, number of supplementary/additional operators; N3, number of alternative techniques used; N4, Cormack grade minus one (eg, N4 = 0 with Cormack grade = 1); N5, lifting force applied during laryngoscopy (N5 = 0, little effort, and N5 = 1, increased effort); N6, is external laryngeal manipulation required (N6 = 0, no, and N6 = 1, yes); and N7, position of vocal cords (N7 = 0, abduction, and N7 = abduction)\textsuperscript{20} (see Box 2).

In the 2003 ASA report on management of the difficult airway, 11 airway examination components along with nonreassuring findings were listed as part of the preoperative airway physical examination\textsuperscript{9} (Table 1).

**Use of Scales and Techniques to Predict Difficult Intubation in Emergency Departments**

Whether or not these various scales and techniques to predict difficult intubation are applicable to emergency department (ED) settings has been questioned for several reasons. First, most of the scales and techniques, including the Mallampati classes, were developed as part of a preoperative anesthesia evaluation or in the controlled
environment of an OR, in which there is time to assess cooperative patients. They were not developed in the chaotic, uncontrolled, usually time-limited urgent or emergency conditions of EDs, which generally involve uncooperative, unfasted, critically ill, or unstable patients. This is underscored by an ED study using three variables, Mallampati class, neck mobility, and thyromental distance, to predict difficult intubation. According to this study, these three physical examination techniques could not be performed on two thirds of ED patients for various reasons, including inability to follow commands or cervical spine immobilization, thereby nullifying its use for emergent airway assessment in the ED.

Even in the 2003 ASA report, there is the acknowledgment that in a patient who does not have obvious pathology, there is no evidence indicating that a difficult airway can be predicted by physical examination, but it is still recommended to do a physical examination to “improve detection of a difficult airway.”

**INTUBATION: SUCCESS RATE AND COMPLICATIONS**

**Non–Emergency Department Intubations**

A prospective multicenter study of ICUs found at least one severe complication in 28% of all intubations. Comorbidity (e.g., shock and acute respiratory failure) was a risk factor for intubation complications, with supervision by a senior physician having a protective effect with fewer complications occurring.

These results are consistent with findings in another ICU study of unplanned endotracheal extubations in which difficulty with reintubation (multiple or prolonged attempts or need for a fiberoptic bronchoscope) was common, occurring in 20% of patients. Another study of the airway management of ICU patients noted major complications in a significant number of patients, including difficult intubations (8%), esophageal intubations (8%), and pulmonary aspiration (4%). Of intubations in an acute care military hospital, 7.9% (22/278) had one or more significant endotracheal tube misplacements of which 23% had serious complications.

**Emergency Department Intubations**

According to the National Emergency Airway Registry (NEAR), a prospective multicenter registry of ED intubations with more than 6000 patients, the intubation success rates for EM residents were first attempt 83% and first intubator 90% with a 0.9% cricothyrotomy rate. The rate of successful intubation increased with
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<td>- Mandibular fractures</td>
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<td>- Limit neck mobility</td>
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<td>- Laryngotracheal trauma</td>
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<td><strong>Nontraumatic conditions/illnesses</strong></td>
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<td>Congenital: osseous abnormalities</td>
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<td>- Limited cervical spine mobility (restricted neck movement)</td>
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<td>- Limited temporomandibular joint mobility (restricted mouth opening)</td>
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<td>- Small mouth (restricted mouth opening)</td>
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<td>- Cleft palate, high arched bony palate</td>
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<td>Congenital: nonosseous/soft tissue abnormalities</td>
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<td>- Macroglossia</td>
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<td>- Protruding upper incisors (buck teeth)</td>
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<td>- Cleft palate, high arched soft palate</td>
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<td>- Small mouth (restricted mouth opening)</td>
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<tr>
<td>Acquired</td>
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<tr>
<td>- Upper airway tumors/malignancies</td>
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<tr>
<td>- Angioedema</td>
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<tr>
<td>- Foreign body in extrathoracic airway</td>
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<tr>
<td>- Upper airway infections: epiglottis, retropharyngeal abscess, peritonsillar abscess, Ludwig's angina, others</td>
</tr>
<tr>
<td>- Hematemesis</td>
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<td>- Vomiting</td>
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There was a 2.7% need for a rescue airway with a 0.0056% (N = 43/7712) incidence of cricothyrotomy in the NEAR study.

A study of ED intubations found a success rate of 74% for EM PG1 versus 100% for EM attending physicians and a cricothyrotomy rate of 1.2% (4/324). Higher first-attempt intubation success rates from 80% to 90% were noted in other ED intubation studies in which the ED intubators were not restricted to first-year residents. This is consistent with the NEAR study and the ICU study, which found the intubation success rate increased with the level of experience.

A study of ED intubations in which rapid sequence intubation (RSI) was used in only 33% of patients noted success rates for ED physicians of 90% for the first attempt and 97% overall success, with only 3% needing airway management by anesthetists and only one cricothyrotomy needed. In another study of ED intubations, EM physicians successfully intubated 99% of patients (321/324), with anesthesia intubating only 1% (3/324) and with cricothyrotomies done in only four patients. In another report of 610 ED patients needing tracheal intubation in which RSI was used in 84% of patients,
93% were intubated by EM residents or attending physicians; 98.7% were successfully intubated; and seven patients underwent cricothyrotomy (7/610 = 0.01%).

A large, prospective, multicenter study of pediatric ED intubations from the NEAR registry (in which RSI was used in 81%) noted a 77% first-attempt success and an 85% success rate for the first intubator. As with the other ED studies, the vast majority (88%) of the initial intubators were in training (residents or fellows). This percent of first success rate is slightly lower than other studies of ED intubations, which suggests that intubations of ED pediatric patients may be more difficult with a lower successful intubation rate than ED adult patients. This pediatric ED intubation study also found that the age of the pediatric patient was a critical factor in determining intubation success with only a 60% first-attempt success in infant/toddlers and preschoolers, 71% in school-aged children, and 85% in adolescents. The first intubator’s success rate showed a similar trend: infant/toddler 79%, preschool-aged 74%, school-aged 86%, and adolescents 94%.

With ED intubations, the need for a rescue airway occurred in 2.7% of emergency intubations and the need for cricothyrotomy ranged from 0.006% to 1.2%, with the highest incidence of cricothyrotomy (1.2%) noted in PG1 residents and the lowest incidence in the NEAR registry database.

The ED incidence of difficult intubations and cricothyrotomies compares favorably with that for anesthesiology. The reported incidence of difficult intubation in anesthesia practice is 1.5% to 18%, with a usual cited rate of 1% to 3%, and 4% according to the Australian Incident Monitoring Study, and need for emergent transtracheal airway at 0.003%. The ED rates in the NEAR study were need for a rescue airway 2.7% and incidence of cricothyrotomy 0.006%.

**Intubation Success Rates: Emergency Physicians and Anesthesiologists**

A comparison of EM resident intubations versus anesthesia-managed intubations at a level 1 training center showed no significant difference between the two groups with first-attempt success rates of 73.7% (EM) versus 77.2% (anesthesia) and overall success rates (three attempts) of 97.0% (EM) versus 98.0% (anesthesia).

In another study of RSI performed outside ORs on emergency patients, there were no significant differences in the complication rate between three types of intubating teams comprised of anesthetists, nonanesthetists, or both.

According to one report, the mean complication rate for ED RSI patients was less for emergency physicians (EPs) than anesthetists. The complication rates (mean) were for anesthetists, trauma patients 17% and nontrauma patients 22%, versus for EPs, trauma patients 14% and nontrauma patients 4%.

Another large prospective study of ED trauma patient intubations found “no differences in laryngoscopy performance and intubation success in trauma airways managed...by emergency medicine versus anesthesia residents” (86.4% versus 89.7% first-attempt success, respectively).

In contrast to these studies, there is one report with slightly different findings. In this study from Scotland, anesthetists had a significantly higher initial success rate (91.8% versus 83.8%) and a better laryngoscopic view (Cormack grades 1 and II) (94.0% versus 89.3%) with a trend to fewer complications (8.7% versus 12.7%) than EPs. EPs, however, intubated a significantly greater number of patients within 15 minutes of arrival (32.6% versus 11.3%). Their conclusion was anesthetists obtained better laryngoscopic views with higher initial success rates during RSI, although EPs performed RSI on a greater percentage of critically ill patients within 15 minutes of arrival.

A best evidence review of studies comparing EPs with anesthetists found “little or no difference in the rates of success and complications” for RSI.
Rapid Sequence Intubation Versus Non–Rapid Sequence Intubation Techniques

The NEAR study indicated that intubation using RSI had higher success rates than non-RSI techniques.\textsuperscript{26} First-attempts/first-intubator success rates were RSI 85%/91% versus oral, no medication 76%/86%. Furthermore, some of the non-RSI techniques were successful on repeat attempts after switching to an alternative technique, most commonly RSI.\textsuperscript{26}

The pediatric NEAR data registry also found higher success rates for RSI than for non-RSI techniques. Successful intubation on the first attempt was RSI 78%, without medication 47% ($P<.01$), and sedation without neuromuscular blockage 44% ($P<.05$). First intubator success rates were RSI 85%, without medication 75%, and sedation without neuromuscular blockage 89% (not significant).\textsuperscript{33}

Other studies collaborate higher rates of successful intubation, fewer complications, and faster intubation completion times with RSI compared with non-RSI endotracheal intubations.\textsuperscript{39–41} In a study of physicians working on board ambulances, significant differences were found when succinylcholine was added to the intubation protocols.\textsuperscript{39} The results of presuccinylcholine versus postsuccinylcholine for tracheal intubation were first-attempt success 55% versus 74%, duration of intubation (minutes) 4.1 versus 1.4, and incidence of complications (hypoxemia, laryngospasm, and bronchospasm) 31% versus 15%.\textsuperscript{39} After the introduction of RSI using etomidate and succinylcholine, an air medical transport program with nurses and paramedics as the intubators reported a significant increase in the first intubation success rate from 65.7% to 79.3%, a decrease in the number of intubation attempts from 105 to 87 or an average from 1.5 to 1.2, and a decrease in the duration of intubation (minutes) from 5.1 to 2.1.\textsuperscript{40}

A prospective study compared ED intubation with RSI (N = 166 patients) and without RSI (N = 67).\textsuperscript{41} They found complications were greater in number and severity in the non-RSI group. Complications observed in the non-RSI group included aspiration (15%), airway trauma (12.8%), and death (3%). None of these complications occurred in the RSI group ($P<.0001$).\textsuperscript{41}

Intubation success rates may depend on a patient’s underlying condition, eg, medical versus trauma, vital signs absent (with absent airway reflexes) versus vital signs present (with airway reflexes present) and whether oral or nasal intubation is done.\textsuperscript{42} A prehospital study of paramedic intubations reported first-attempt/overall success rates for medical emergencies 60.4%/74.3%, trauma patients 66.6%/71.4%, and patients who had vital signs absent 80.1%/96% and for nasal compared with oral intubations (63% versus 94%). Whether or not the significant differences for medical or trauma patients compared with patients who had absent vital signs are related to preserved airway reflexes in the former versus absent reflexes in the latter or to other factors (training, experience, technical difficulties, and so forth) remains to be determined.\textsuperscript{42}

Complications of Intubation

Many complications are associated with intubation. In one report, oxygen desaturation was reported as the most common complication of emergency RSI followed by hypotension.\textsuperscript{35} Immediate complications of emergency RSI noted in one study from Britain included hypoxemia (19.2%), hypotension 17.8%, and dysrhythmia 3.4%.\textsuperscript{35} The probability of complications was significantly associated with patients’ underlying conditions, with hypoxemia occurring more frequently in patients who had underlying respiratory or cardiovascular conditions.\textsuperscript{36} An ICU study also correlated an increased
risk for complications during intubations with pre-existing shock or acute respiratory failure.22

A study of ED intubations in the United States found that 8.0% (49/610) of patients had an immediate complication with a total of 9.3% (57/610) immediate complications (some patients had more than one complication).30 When inadvertent esophageal placement did occur (5.4% = 33/616), it was quickly recognized and corrected. There were three postintubation cardiac arrests; two patients had agonal rhythms before intubation and one likely had a succinylcholine-induced hyperkalemic cardiac arrest.30

Similar findings were reported in another study of ED intubations in which complications occurred in 10.3% of patients (22/214) with a total complication rate of 14.9% (32/214).32 Complications included esophageal intubation 6.1% (13/214), soft tissue damage 3.3% (7/214), oxygen desaturation 1.9% (4/214), hypotension 1.4% (3/214), bronchial intubation 1.4% (3/214), dental trauma (1/214), and dysrhythmia (1/214).32

**Elements for Best-Attempted Conventional Laryngoscopy**

According to some experts, the best attempt at conventional laryngoscopy is predicated on six elements: performance by a reasonably experienced practitioner, no significant muscle tone, an optimal sniffing position, blade length, blade type, and use of laryngeal manipulation. Unfortunately, in the ED setting, optimizing all six variables may not be possible. For example, for a trauma patient who has suspected or known cervical spine injury, positioning in a sniffing position is not possible.

**CONTROVERSIES WITH RAPID SEQUENCE INTUBATION**

Although RSI is standard of care,41,43–45 several issues and controversies have arisen.

**Step 2: Preoxygenation**

Ideally, preoxygenation (step 2) is accomplished by having patients breathe 100% oxygen via a tight fitting facemask for 3 to 5 minutes and avoiding BVM to prevent gastric distention. Unfortunately, in the ED allowing time, even 3 to 5 minutes may not be feasible.45 Furthermore, many ED patients have ineffective breathing or are apneic so BVM is necessary. Although adults who have normal functional residual capacity (FRC) can tolerate up to 5 minutes of apnea before they desaturate,46 many if not most ED patients undergoing RSI do not have a normal FRC. Patients who have a limited FRC may desaturate within 2 minutes if apneic. Patients who have a limited FRC in danger of rapidly becoming hypoxic include infants, children, pregnant females, obese adults, patients who have an elevated diaphragm (eg, bowel obstruction), and patients who have underlying lung disease (eg, interstitial lung disease). A recent study documented that patients who have respiratory failure as a result of underlying cardiopulmonary disease frequently do not respond to the standard mode of preoxygenation.47 Only half of such patients had an increase in PaO2 greater than 5% above baseline with the standard 4-minute preoxygenation.47 Another prospective randomized study of ICU patients found better PaO2 and pulse oximetry values using noninvasive positive pressure ventilation (NIPPV) than with conventional preoxygenation before endotracheal intubation.48

In summary, the preoxygenation phase (step 2) should allow adequate oxygenation for most patients such that BVM ventilation should be avoided if possible during RSI because of an increased risk for regurgitation and aspiration from gastric distention secondary to BVM. Some patients who have hypoxemia, apnea, inadequate
ventilation, or respiratory distress/failure, however, may need BVM before, during, and after RSI. BVM should not be withheld from such patients.

**Step 3: Pretreatment**

With the pretreatment phase (step 3), questions include which drugs should be given and in what doses? The routine use of atropine for pediatric RSI has been questioned recently although the two cited studies had methodologic flaws (eg, insufficient power and design). It has been theorized that a component of the bradycardia noted during pediatric RSI with succinylcholine may be the result of the hypoxia and underlying diseases or conditions and not just to the administered medication. Whether or not this is the case may be irrelevant because symptomatic bradycardia, whatever the cause, is treated with atropine. The current consensus for pretreatment in RSI suggests (1) lidocaine and fentanyl for patients who have significant central nervous system trauma or disease (eg, elevated intracranial pressure), (2) fentanyl in patients who have vascular dissection/rupture or ischemic heart disease or anyone who would be affected negatively by reflex sympathetic nervous system–mediated discharge of catecholamines that leads to a transient but significant rise in blood pressure and heart rate, (3) lidocaine if acute asthma or bronchospasm (wheezing) is present, and (4) atropine if a pediatric patient (< 10 years old) or any patient who has significant bradycardia when succinylcholine is to be given.

**Step 4: Paralysis with Induction**

Decisions that arise with step 4—paralysis with induction—include the sedative choice, whether or not to use succinylcholine or a nondepolarizing neuromuscular blocking agent, and doses of the drugs. When succinylcholine is the paralytic agent, which pretreatment drugs should be used and when to use them has been controversial. In view of the associated risks and complications with a defasciculating dose of a nondepolarizing neuromuscular blocking agent is not widely used in ED RSI, in view of the associated risks and complications associated with defasciculating doses of these drugs, although lidocaine, fentanyl, and atropine are used in some cases.

**Step 5: Protection and Positioning—Cricoid Pressure**

The use of cricoid pressure in step 5 (protection and positioning) has been questioned. Although cricoid pressure is routinely recommended in RSI, problems can occur and there are no outcome studies documenting the clinical advantages of the Sellick maneuver. Because of these concerns, some experts have suggested that the use of the Sellick maneuver during RSI and bag mask ventilation be considered optional, noting that “there is little evidence to support the widely held belief that application of cricoid pressure reduces the incidence of aspiration during RSI” and cricoid pressure may actually “worsen the quality of laryngeal exposure” thereby making endotracheal intubation more difficult.

The purpose of cricoid pressure is to prevent regurgitation of gastric contents into the lungs. Whether or not cricoid pressure actually accomplishes this has been challenged recently. The esophagus was lateral to the larynx in over 50% of the awake volunteers in a recent MRI study. Furthermore, cricoid pressure increased (not decreased) the incidence of an unoccluded esophagus by 50% and caused airway compression (>1 mm) in 81% of the subjects studied. This report, however, differs from the results of two studies (a cadaver study and a clinical study) that documented decreased gastric insufflation with air during mask ventilation when cricoid pressure was applied. This raises the question or whether or not studies with mask ventilation can be applied to endotracheal intubation and what effect, if any, cricoid
pressure has on preventing gastric aspiration during endotracheal intubation. A literature review of 241 articles dealing with cricoid pressure concluded there was little evidence to support the view that cricoid pressure decreases the risk for aspiration.58

There are data suggesting that cricoid pressure may worsen the degree of laryngeal exposure. A study compared cricoid pressure with backward, upward, and rightward pressure (BURP) on the thyroid cartilage and bimanual laryngoscopy by an endoscopist.63 The Sellick maneuver and BURP actually worsened the laryngoscopic view.63 Other studies also have found that cricoid pressure may worsen the laryngeal/glottic view.64,65 This may be why there have been instances of regurgitation and aspiration in spite of appropriate use of cricoid pressure. Some reports have indicated that use of the Sellick maneuver may cause airway obstruction and increase the difficulty of intubation.66–68 Furthermore, cricoid pressure may cause unwanted significant increases in the heart rate and blood pressure.69

Disadvantages cited with use of cricoid pressure include visualization of the larynx/glottis is more difficult and airway obstruction can occur, making intubation more difficult; movement of the cervical spine can occur; and possible esophageal injury in actively vomiting patients.

Furthermore, a review of the Sellick maneuver indicated that cricoid pressure may be applied inconsistently and incorrectly during an emergency, even by health care workers who often perform the procedure.70,71

Currently, although the effectiveness of the Sellick maneuver in preventing regurgitation has been questioned, and its use considered optional by some, occasionally it may be beneficial. Therefore, cricoid pressure may be applied at least initially with RSI. If the use of cricoid pressure obscures the view of the glottis, hampers endotracheal tube passage, or impairs adequate BVM ventilation, however, then cricoid pressure should be immediately decreased or eliminated. It may be that a variant of the Sellick maneuver, however, optimal external laryngeal manipulation, may be beneficial in improving the laryngeal/glottic view.63

**Step 5: Protection and Positioning—Positioning of Patients**

The classic teaching is to place patients in the sniffing position with the neck flexed and the head slightly extended about the atlantooccipital joint before intubation to align the three axes: oral, pharyngeal, and laryngeal (see Fig. 6). A recent randomized MRI study in general surgery patients in ORs questioned the use of the sniffing position.72 Another randomized study in ORs found that simple head extension was as effective as the sniffing position in facilitating endotracheal intubation.73 Similar studies in ED patients are lacking so whether or not these reports in ORs can be generalized to ED patients is unknown.

ED patients who have known or possible cervical spine injury needing intubation pose a special challenge. The best mode of endotracheal intubation in such patients is a controversial topic.74 Several studies suggest, however, that removing the anterior part of the cervical collar, while maintaining manual in line cervical spine immobilization, is acceptable and may cause less cervical spine movement than cervical collar immobilization during laryngoscopy for endotracheal intubation.75,76

Nontrauma patients associated with a decreased range of neck motion include patients who have degenerative disc disease and patients’ status post cervical spine surgery/instrumentation. Among those who have degenerative disk disease are the elderly (age >70 years) and patients who have rheumatoid arthritis, osteoarthritis, and ankylosing spondylitis.

In morbidly obese patients, a better view of the larynx was obtained with ramped positions using blankets underneath a patient’s body and head to obtain a horizontal
alignment between the external auditory meatus and the sternal notch rather than with the sniffing position. Although this study was done in morbidly obese patients undergoing elective bariatric surgery, it seems logical that this also may apply to morbidly obese patients undergoing intubation in the ED. Because of physiology with decreased expiratory reserve volume, forced vital capacity, forced expiratory volume in 1 second, and maximum voluntary ventilation, the morbidly obese are more susceptible to hypoxemia than normal weight individuals. Furthermore, the body habitus of morbidly obese patients may make repositioning difficult or impossible during endotracheal intubation.

CLINICAL RESPONSES TO INTUBATION

There are many negative clinical responses to intubation. The goal of RSI is to minimize or prevent some of these detrimental clinical responses. A review of the clinical responses to intubation and the pathophysiology is useful to understand RSI.

The cardiovascular reflexes to intubation are initiated by proprioceptors in the supraglottic region and trachea. Afferent neural impulses travel via the vagal (cranial nerve [CN] X) and glossopharyngeal (CN IX) nerves to the nucleus tractus solitarius (NTS) in the medulla with efferent activation of both divisions of the autonomic nervous system. In infants and small children, bradycardia, bradypnea, and even apnea can occur during laryngoscopy or intubation. This is secondary to increased parasympathetic (vagal) tone, including at the sinoatrial node. Upper airway reflexes; including laryngospasm (eg, the glottic closure reflex) and the sneeze, cough, and swallow reflexes, are essentially monosynaptic responses to an irritant stimulus in the airway. Conversely, in adults and adolescents, increased heart rate and blood pressure are the typical responses to airway manipulation. This response is mediated via postganglionic cardioacceleratory nerves from the paravertebral sympathetic chain ganglia, which includes norepinephrine release from adrenergic nerve terminals and the secretion of norepinephrine from the adrenal medulla. Stimulation of the β-adrenergic nerves to the renal juxtaglomerular apparatus activates the renin-angiotensin system resulting in the release of renin, which further raises the blood pressure.

Stimulation of the central nervous system caused by activation of the autonomic nervous system leads to elevations in the cerebral metabolic rate, oxygen consumption, and cerebral blood flow. This could have disastrous consequences in patients who have impaired CNS autoregulation or elevated intracranial pressure from illness or trauma. Any rise in heart rate or blood pressure causes an increase in myocardial oxygen demand, which in turn, could lead to myocardial ischemia in patients who have coronary artery insufficiency. Patients who have any vascular dissection/rupture or a vascular aneurysm/arteriovenous malformation could be adversely affected by a rise in arterial blood pressure.

Airway reflexes, such as coughing or vomiting, can lead to elevated intrathoracic and intra-abdominal pressure, which could worsen many conditions (such as decreased cardiac output secondary to impaired venous return from increased intrathoracic pressure or abdominal distention/rupture) and create new problems (eg, Mallory-Weiss tear or Boerhaave’s syndrome or aspiration). Increased cerebrospinal fluid pressure secondary to an elevated intrathoracic and intra-abdominal pressure results in increased intracranial pressure.

PATHOPHYSIOLOGY OF INTUBATION

CN IX (glossopharyngeal) and CN X (vagus) innervate the upper airway and digestive tract mucosa. Afferents from the CN IX and X project to the solitary tract-nucleus (NTS) in the medulla.
The NTS serves as the visceral sensory (visceral afferent) nuclei of the brainstem. The NTS receives the afferent fibers from CN IX, X, and VII (facial) nerves. Nerve impulses originating in the pharynx, larynx, intestinal tract, respiratory tract, heart, and large blood vessels are processed in the NTS. The NTS receives sensory input from all the viscera of the thorax and abdomen.

The vomiting or emetic center, an anatomically indistinct group of receptor and effector nuclei in the NTS coordinates the efferent (autonomic, respiratory, and gastrointestinal) activity related to vomiting. The area postrema, located in the floor of the fourth ventricle, can react to stimuli in the blood or cerebrospinal fluid and provides afferent input to the vomiting center in the NTS.

The upper airway reflexes include the glottic closure reflex (laryngospasm), cough, sneeze, and swallow reflex. The function of the various upper airway reflexes is to protect the respiratory system and gas exchange surface from foreign or noxious substances. This is why there is a profusion of sensory nerve endings in the airway and rapid motor responses to any stimuli in the airway.

The glossopharyngeal (CN IX) and the vagus (CN X) nerves serve as the afferent nerve pathways for these upper airway reflexes and for the cardiovascular responses to endotracheal intubation. When the airway stimuli are located superior to the anterior epiglottic surface, then the afferents travel via the glossopharyngeal nerve to the NTS. When the stimuli are at or below the posterior epiglottic surface, continuing interiorly into the lower airway, the vagus nerve serves as the afferent pathway to the NTS. Stimulation of the airway mechanoreceptors or nociceptors can trigger any of these airway reflexes.

Parasympathetic nerves innervate the airway smooth muscle, vasculature, and the mucus glands of the airway. Parasympathetic (vagal) stimulation causes mucus secretion, and dilatation of airway blood vessels. The sympathetic nerves also innervate the airway vasculature. Sympathetic stimulation causes vasoconstriction of airway blood vessels. Upper airway sympathetic efferent nerves arise from the trigeminal ganglion.

Activation of the NTS causes stimulation of the sympathetic nervous system with an increase in heart rate and blood pressure than can foster dysrhythmias and a rise in intracranial pressure and intraocular pressure.

Bronchospasm also can occur as a reflex response to endotracheal intubation and may occur even in patients who have no history of asthma or obstructive lung disease. Efferent parasympathetic fibers travel to the bronchial smooth muscle and stimulate the M3 cholinergic fibers on the bronchial smooth muscle, causing a cholinergically mediated bronchoconstriction. Stimulation of the laryngeal and upper tracheal airway receptors can cause airway constriction in the large and smaller peripheral airways, which results in a reflex mediated increase in airway resistance.

SUMMARY

Management of the airway is the first priority in any patient. Dealing with a difficult airway can be a challenge, whether or not it involves BVM ventilation, an intermediate airway device, laryngoscopy and intubation, or a surgical airway. Various scales have been devised to predict which patients are likely to have a difficult airway. Irrespective of the location, ED, ICU, or OR, the issues regarding intubation, including complications and success rates, are somewhat similar. The goal of RSI is to eliminate or mitigate the untoward reflex responses to intubation. Knowing the pathophysiology and negative clinical responses associated with intubation is useful in understanding the procedure of RSI. Although controversy has arisen regarding the various steps in RSI, it remains an essential component of EM practice.
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