Preoperative planning of airway management in critical care patients

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Objective: **The aim of this article is to review aspects of airway evaluation that may affect the care of the critical care patient whose airway is to be managed. This information must then be incorporated into the decision-making process of the "airway manager."**

Design: **Literature review.**

Results: **Historically used indexes of airway evaluation suffer from low sensitivity and only modest specificity in identifying the difficult-to-intubate patient. Using each index in isolation of others contributes to their poor predictive power. An understanding of anatomical relationships that these indexes measure should help the clinician in evaluating the airway. The clinician's impression of the airway, as well as the likelihood of trouble with supraglottic ventilation, the patient's inability to take food orally, and the patient's general condition can be used to formulate a management plan. This plan should be consistent with the American Society of Anesthesiologist's difficult airway algorithm.**

Conclusions: **Rote decision making on airway management, based on commonly used indexes, is not adequate. The vital role of airway in anesthetic management of the critical care patient demands thoughtful consideration. Patient conditions including the need for airway control, the likelihood of difficult laryngoscopy or supraglottic ventilation, the patient's inability to take food orally, and the medical state of the patient must be incorporated. (Crit Care Med 2004; 32[Suppl.]:S186–S192)**

KEY WORDS: airway evaluation; indexes of airway evaluation; intubation; anesthetic management

The induction of anesthesia for surgery in the critical care patient introduces a collateral set of potential morbidities that may be unrelated to the pathology demanding surgical intervention. One such issue is the effect of anesthesia on the ability of the patient to maintain and protect his or her own airway. Most hypnotic agents, as well as analgesics, amnestics, and, of course, muscle relaxants will obtund the protective airway reflexes and thwart oxygenation and ventilation. It is incumbent on the anesthesiologist preparing the critical care patient for surgery to plan airway management in a way that minimizes the likelihood of contributing morbidity to the patient's postoperative course. This plan must be based on a careful consideration of five separate but equally important issues (Table 1). This review will consider each of these issues and how the they affect the plan for airway management in the critical patient. Although the literature is replete with discussions of each, the clinician's experience and the effect it has on interpretation of data may have the most significant effect. For example, the Australian Incident Monitoring Study revealed that 70% of difficult airways are identified preoperatively. No single airway index has been shown to be as sensitive (1). This review will not rehash all the data that can be found in the standard texts of airway management. For this the reader is referred elsewhere (2).

The gold standard in formulating a preoperative airway plan is the American Society of Anesthesiologists' difficult airway algorithm (DAA) (3, 4). These guidelines, first published in 1993 and updated in 2003, are poorly named. The airway management of all patients undergoing general anesthesia with tracheal intubation follows an arm of the DAA (Fig. 1). One root point and two branches of the algorithm apply to difficult airways: when difficulty with the airway is anticipated (root point A), when a cannot-intubate/cannot-ventilate situation arises (emergency pathway branch), and when face mask or laryngeal mask airway ventilation deteriorates in the cannot-intubate patient (nonemergency pathway to emergency pathway branch). The two pathway branches may be entered after the clinician has commenced routine airway management, and they imply a significant risk of an airway-related patient morbidity. Because the stated objective of this discussion is to avoid such problems, the central thrust will be the recognition of the difficult airway so that the American Society of Anesthesiologists algorithm can be entered at the safest point, that is, at the anticipated difficult airway root (5).

Should all airways be managed with the expectation that there will be difficulty with intubation and/or ventilation? No. Treating all airways as "difficult" has its own incidence of morbidity (Table 2). Only airways that are judged as unsafe to manage in a routine manner deserve to enter the anticipated difficult airway root point of the DAA.

Identifying the truly difficult airway is not only arduous but is also multileveled. An airway may be difficult for mask ventilation, supralaryngeal ventilation, direct laryngoscopy, direct laryngoscopy and tracheal intubation, or intubation by other means (e.g., fiberoptic bronchoscope, retrograde wire, intubating laryngeal mask, etc.). A logical decision tree approach to airway evaluation has been synthesized into an "airway approach algorithm" (AAA) based on the five questions in Table 1 (5). The AAA is meant to be used by the clinician before the induc-

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Table 1. Issues considered in planning airway management

1.	Is airway management necessary?
2.	Will direct laryngoscopy and tracheal intubation be straightforward?
3.	Can supralaryngeal ventilation be used?
4.	Is there an aspiration risk?
5.	In the event of airway failure, will the patient tolerate an apneic period?

tion of anesthesia to organize information vital to airway evaluation, choose an appropriate DAA root point, and avoid the emergency pathway branches of the DAA. The AAA's preoperative evaluation sequence is meant to resemble the succession of the American Society of Anesthesiologists algorithm: If during the sequential preoperative evaluation the equivalent of the emergency pathway is reached, the clinician has the luxury of commencing airway management at the anticipated difficult airway root point.

Is Airway Management Necessary? Although possibly the most common physiologic function to be controlled by the anesthesiologist, the induction of apnea can never be considered casually. By rendering the patient apneic, the anesthesiologist has placed the patient at significant risk: If the airway cannot be controlled, life hangs in the balance. For this reason the AAA starts with the question, "Is general anesthesia required for the surgical procedure at hand?" This decision may not be solely answered by the anesthesiologist: The surgical procedure, surgeon, and patient may not be amenable to regional or infiltrative anesthetic techniques. Given the particulars of the situation, as well as the anesthesiologist's own comfort with specific regional techniques, the anesthesiologist must be the chief decision maker in this situation.

Of course, airways are "managed" in more than just general anesthetics. Regional anesthesia and local infiltration cases and invasive procedures performed with or without sedation may all require either a degree of airway manipulation or conversion to a general anesthetic. This illustrates the importance of all the questions of the AAA being answered (e.g., all the information gathered) even if a nongeneral anesthetic technique is chosen.

Is There Potential for a Difficult Laryngoscopy? Once the decision to use general anesthesia—with or without the induction of apnea—is made, the next question to be answered is whether there is any indication that standard direct laryngoscopy will be difficult. Although other techniques of tracheal intubation have become ubiquitous and may be more versatile (e.g., flexible fiberoptic aided intubation), direct laryngoscopy and tracheal intubation remain a standard of care in most of the world (6–9). It is generally accepted that tracheal intubation provides the best airway control, protection from aspiration, and ability to ventilate with high airway pressures. In most hands, direct laryngoscopy can be used to achieve tracheal intubation faster than other techniques.

The question of ease of direct laryngoscopy and tracheal intubation is approached with a careful and focused review of the patient's history and physical evaluation of the airway. The commonly employed methods of physical evaluation include a measure of mouth opening, an oropharyngeal score, thyromental distance, and chin protrusion. The size of the mouth opening (interincisor gap) may be rated as small, normal, or wide (a 4-cm gap being considered optimal). The oropharyngeal score (known as the Mallampatti score, as modified by Samsoon and Young) (10–12) rates airway visualization, and hence progressive difficulty, on a I–IV scale as the patient sits upright, voluntarily opens the mouth, extends the tongue and does not vocalize: I, hard and soft palates, uvula, fauces, pillars; II, hard and soft palates, uvula, fauces; III, hard and soft palates, possibly uvula base, possibly part of fauces; and IV, hard palate only. Thyromental distance may be rated as $>$6 cm or $<$6 cm. Chin protrusion (voluntary anterior displacement of the mandible) may be rated as adequate (the lower incisors can be extended anterior to the upper incisors) or negative (lower incisors meet or are posterior to the upper incisors; Table 3) (10–13).

Despite this, these indexes can still be useful. Their routine application to all patients accounts for their disappointing reliability. More judicious use can improve their utility. For example, both Ayoub et al. (14) and Iohom et al. (15) have found that by segregating groups by the length of the thyromental space, the sensitivity of the Mallampati classification can be improved (15, 16). Ayoub et al. (14) found that when the distance from the thyroid cartilage to the most anterior portion of the mentum was $>$4 cm, the Mallampati grade had no correlation with the best view obtained of the larynx during direct laryngoscopy. Iohom et al. (15) had similar findings using a thyromental distance cutoff of 6 cm. In addition, even when an adequate thyromental distance is present, other factors, such as a history of submandibular trauma, radiation, or surgery, may render the tissues immobile regardless of the length.

The physical exam of the airway and the variety of indexes that are used have been described elsewhere, although little attention is given to the rationale for the application of these tests. Functional airway assessment is a technique that considers the relationship between the various physical indexes and how changes in one anatomical finding relate to another.

Chou et al. (16) have described a two-axis model of the airway based on magnetic resonance imaging studies. With the head held in the neutral position, the oral and pharyngeal axes intersect at a 90° angle (Fig. 2*A*). Extension of the head on the neck typically achieves a 125° angle (an improvement, but hardly what is required to provide a line of site to the larynx; Fig. 2*B*). Flexing the neck on the chest, which achieves the "sniffing" position originally described by McGill, does not improve this line of site as has been shown in other MRI studies by Bannister and Macbeth (17) and Adnet et al. (18).

Although the angle between the axes cannot be converted to the necessary 180°, displacement of the soft tissues anterior to their juncture (i.e., the tongue) is achieved with the use of the laryngoscope, providing the line of site (Fig. 2*C*). Although malleable, the tongue is not compressible. Consequently, it must be displaced into an available compartment. As the blade of the laryngoscope is lifted against the tongue, it is moved into the normally pliable, thyromental space. The thyromental space is bordered superiorly by the mentum, inferiorly by the semifixed hyoid bone, and laterally by the anatomical boundaries of the neck. If this space is large, as described by Ayoub et al. (14) and Iohom et al. (15), virtually any size tongue (within normal variation) may be displaced into it. When the thyromental space is small, only a relatively small tongue will be displaced adequately (14, 15). If, on the other hand, the space has been affected by the pathologic factors mentioned previously and is no longer distensible, the size of the space as well as the size of the tongue may be

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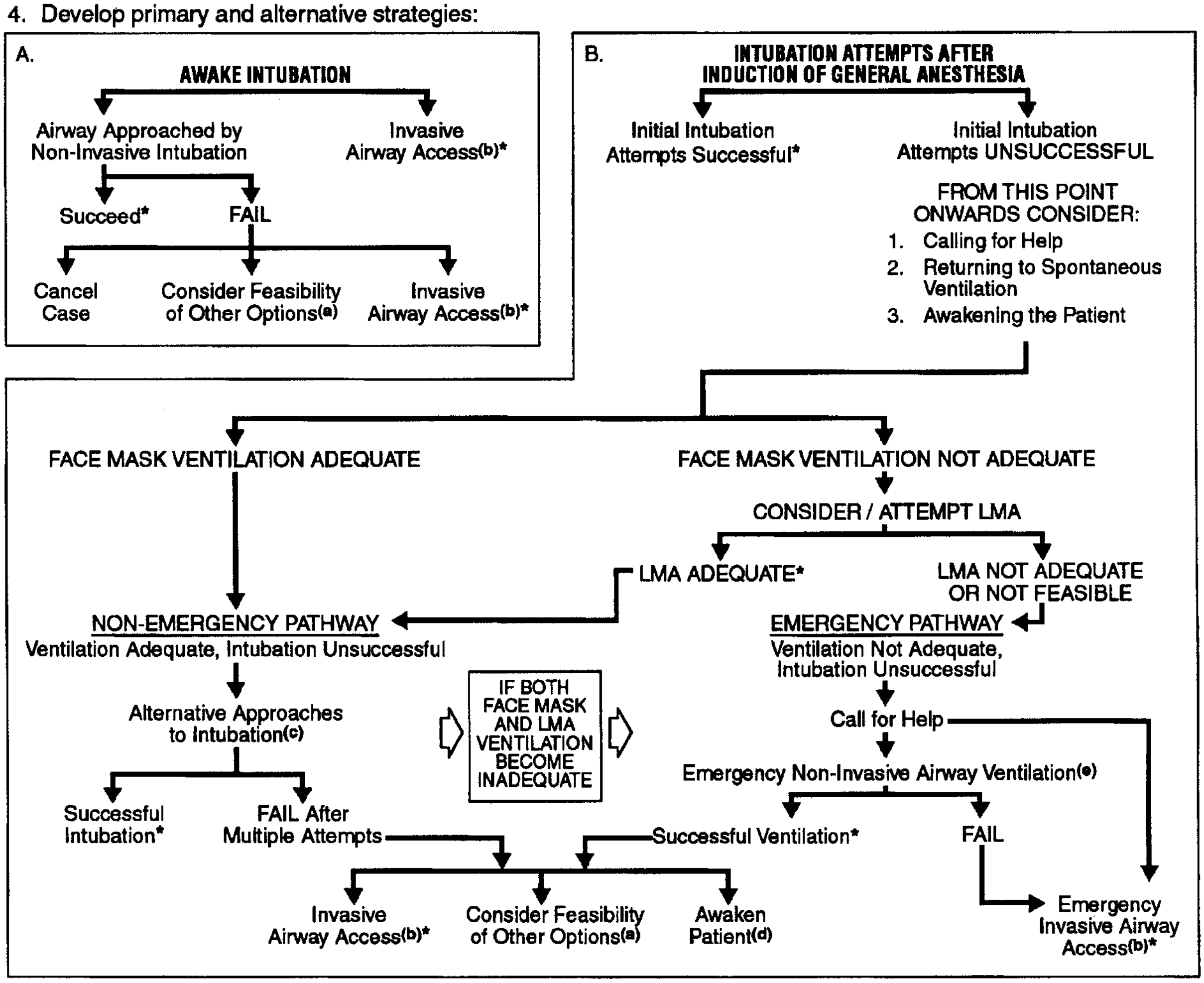
DIFFICULT AIRWAY ALGORITHM

1. Assess the likelihood and clinical impact of basic management problems:
   - A. Difficult Ventilation
   - B. Difficult Intubation
   - C. Difficulty with Patient Cooperation or Consent
   - D. Difficult Tracheostomy
2. Actively pursue opportunities to deliver supplemental oxygen throughout the process of difficult airway management
3. Consider the relative merits and feasibility of basic management choices:
   - A. Awake Intubation —vs.— Intubation Attempts After Induction of General Anesthesia
   - B. Non-Invasive Technique for Initial Approach to Intubation —vs.— Invasive Technique for Initial Approach to Intubation
   - C. Preservation of Spontaneous Ventilation —vs.— Ablation of Spontaneous Ventilation
4. Develop primary and alternative strategies:



*** Confirm ventilation, tracheal intubation, or LMA placement with exhaled CO_2**

a. Other options include (but are not limited to): surgery utilizing face mask or LMA anesthesia, local anesthesia infiltration or regional nerve blockade. Pursuit of these options usually implies that mask ventilation will not be problematic. Therefore, these options may be of limited value if this step in the algorithm has been reached via the Emergency Pathway.

b. Invasive airway access includes surgical or percutaneous tracheostomy or cricothyrotomy.

c. Alternative non-invasive approaches to difficult intubation include (but are not limited to): use of different laryngoscope blades, LMA as an intubation conduit (with or without fiberoptic guidance), fiberoptic intubation, intubating stylet or tube changer, light wand, retrograde intubation, and blind oral or nasal intubation.

d. Consider re-preparation of the patient for awake intubation or canceling surgery.

e. Options for emergency non-invasive airway ventilation include (but are not limited to): rigid bronchoscope, esophageal-tracheal combitube ventilation, or transtracheal jet ventilation.

Figure 1. Difficult airway algorithm.

inconsequential. This approach explains the relative insensitivity of the Mallampati classification, unless the thyromental space is accounted for (14, 15). Last, the ability to translate the temporomandibular joint, which has also been shown to be predictive of larygoscopic score, should improve the ability to displace the tongue away from the line of site by virtue of expanding the anteroposterior size of the space (19) (Fig. 2*D*).

An additional factor, which is difficult to evaluate on routine the preoperative exam, is lingular tonsil hyperplasia. Ovassapian et al. (20) identified enlarged lymphoid tissue at the base of the tongue as the most common cause of unanticipated difficult intubation. Although the concept of functional airway assessment can account for the difficulty that lingular tonsil hyperplasia causes (reduced ability to displace the enlarged base of tongue), routine physical exam will not detect this anatomical variation. Unless lingular tonsil hyperplasia is routinely examined for (e.g., by indirect fiberoptic or mirror examination), a small number of unanticipated difficult direct laryngoscopies will be unavoidable.

The size of the interincisor gap is crucial for the manipulation of instrumentation introduced into the mouth. As illustrated in Figure 3, the ability to open the mouth should affect the ability to create a line of site to the larynx. This can be explained functionally by considering the relationship of the oral aperture and the cross-sectional diameter of the laryngoscope (Fig. 3). As the angle formed between the plane of the blade and the plane of the mandibular incisors decreases, the cross-sectional length presented to the oral aperture increases. Therefore, a narrow interincisor gap will not allow adequate manipulation of the laryngoscope.

Other historical findings, including chipped or broken teeth, past postoperative dysphonia, sore throat, mandible or temporomandibular joint pain, or the patient's memory of tracheal intubation may offer further clues to a prior difficult airway management scenario. Of course, time changes many things, including airways. A patient who was managed easily months or years earlier may not be as easy to manage today. Weight gain, new-onset snoring, arthritic disease, or the pathology that now requires surgical intervention may all have led to a change in the airway. The anesthesiologist should be particularly wary in the patient who was managed successfully, but with difficulty, in the past. Small changes in a variety of systems may tip the balance of airway management: A history of previous difficult airway management is more revealing than a history of an easy airway.

If a definitive decision is made that the airway can be managed with direct laryngoscopy, the competent anesthesiologist should be able proceed with the induction of anesthesia, even if the plan calls for the use of a technique other than direct laryngoscopy. Should direct laryngoscopy fail, the unanticipated difficult airway branches of the DAA are followed.

Can Supralaryngeal Ventilation Be Used? This is perhaps the most significant question in the AAA. Failed tracheal intubation should be inconsequential if ventilation may be achieved by other means. Although supralaryngeal airways were available at the time of the writing of the first American Society of Anesthesiologists difficult airway algorithm, there was limited experience with them as routine (elective) or rescue airway control devices. Almost a decade later, a significant fraction of anesthetics are managed electively with these devices (21). The recent republication of the DAA recognized the importance of supralaryngeal airways, in particular the laryngeal mask airway (LMA) (4). In the recent revision, failure of ventilation by mask, previously branching into the emergency pathway, now recommends immediate application of one of the LMA devices. If failure with the LMA occurs, the emergency pathway is entered.

In clinical practice (as well in the DAA), face mask ventilation is considered the primary supralaryngeal ventilation device. In 2000, Langeron et al. (22) investigated the incidence and predictors of difficult mask ventilation. Among 1,500 patients, they found that 5% could be characterized as having a modestly to very difficult face mask airway. Only one patient was impossible to mask ventilate. Finding two of a possible five clinical factors on preoperative exam was predictive of difficulty with mask ventilation (Table 4).

The other supralaryngeal device ubiquitous in the operating room is the LMA. Success rates for LMA placement are as

Table 2. Factors associated with elective "difficult airway" management

Tachycardia and hypertension
Bradycardia and hypotension (from over treatment)
Local anesthetic toxicity
Laryngeal trauma
Aspiration

Table 3. Statistical reliability of common physical indexes of airway evaluation

Physical Index	ICC	Sensitivity	Specificity
Interincisor gap	.93	.26	.94
Thyromental distance	.74	.65	.81
Chin protrusion	.66	.29	.85
Oropharyngeal grade	.49	.4–.67	.52–.84

ICC, intraclass correlation coefficient. From Refs. 10–13.

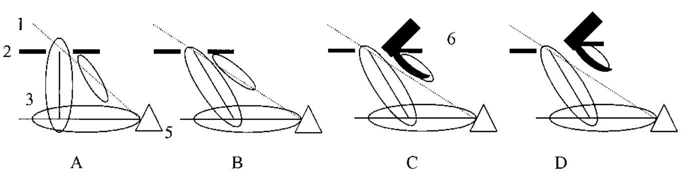


Figure 2. Schematic of the upper airway during laryngoscopy. *A*, relationship of line of sight from the intubator's eye to the larynx, with the head in the neutral position. *B*, relationships during extension of the head on the neck and maximal possible alignment of the airway axes. *C*, relationships with the placement of the laryngoscope. *D*, relationships with maximal anterior-caudad force applied to the laryngoscope, with displacement on the tongue into the thyromental space. *1*, line of sight; *2*, teeth; *3*, oral and pharyngeal axes and cavities; *4*, tongue; *5*, larynx; *6*, laryngoscope.

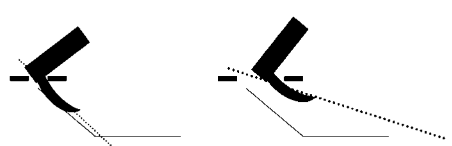


Figure 3. Schematic of relationship between interincisor gap and laryngoscope.

Table 4. Preoperative clinical predictors for difficult face mask ventilation

Body mass index >26
Age >56 yrs
Edentulous
History of snoring
Facial hair

high as 80–99.8% among experienced users (22, 23). Among novice users, the LMA has higher success rates than direct laryngoscopy and face mask ventilation (24, 25, 26). LMA rescue rates (i.e., successful use in situations in which other techniques have failed to secure the airway) are unknown; however, extrapolated data from studies such as Parmet et al. (27) demonstrate success rates of up to 94% and possibly higher depending on the stratification of patients.

There has been little description of the factors likely to contribute to LMA failure. The case report literature may be helpful in this regard. Well-described situations in which LMAs have failed include a patient with a tracheal thrombosis, two cases of tracheal stenosis, one laryngeal carcinoma, one patient with Hunter syndrome, obstetrical patients, and one case each of severe rheumatoid arthritis, medialization of the superior cornu of the thyroid, and meconium aspiration. These patients can be divided into distinct classes that include inability to align the oral and pharyngeal axes, space-occupying lesions in the hypopharynx, and lesions below the hypopharynx including high airway pressure (27–32).

As with question 2 of the AAA, the clinician should proceed to the next question only if he or she is satisfied that supralaryngeal ventilation will be adequate by either face mask, LMA, or other devices with which he or she is experienced in using. If the clinician doubts his or her ability to control the patient's airway by one of these means, the operator is steered toward the anticipated difficult airway root point of the DAA (3, 4).

This approach to the difficult airway root point of the DAA illustrates the juxtapositions of the AAA, the DAA and daily practice. Consider the clinical situation where a patient has been induced with a general anesthetic, cannot be intubated (with direct laryngoscopy), and cannot be ventilated (by face mask or other available supralaryngeal device)—the classic "cannot intubate/cannot ventilate" scenario. By answering question 3 in the negative (i.e., "no, supralaryngeal ventilation may not be possible"), the clinician has arrived at the same scenario but in a predictive sense, before the patient has been placed at risk: The evaluation has reached the cognitive equivalent of "cannot intubate" and potential "cannot ventilate." If this had occurred during the induction of anesthesia, the emergency pathway of the DAA would be entered. Because when using the AAA we are working in a cognitive arena, we still have the option of never entering the emergency pathway and can choose awake pathway management with an alternative technique, such as the fiberoptic intubation scope. It is true that the clinician may err in answering question 2 or 3, resulting in unnecessarily undertaking awake intubation, but the error is made in favor of patient safety. It would be foolhardy to induce anesthesia in a patient you were not sure you could intubate (with direct laryngoscopy) or ventilate by any means.

Is the Stomach Empty? (Is There an Aspiration Risk?) The nonfasted patient, the patient with delayed gastric emptying, and the patient with severe, poorly controlled reflux should not be ventilated by supralaryngeal means. The literature regarding what constitutes a nonfasted patient or the significance of gastroesophageal reflux is beyond the scope of the current discussion.

During the period of supralaryngeal ventilation, the airway is relatively unprotected and there may be an increased risk of regurgitation by virtue of gastric distension. Although the gold standard for tracheal protection is the cuffed tracheal tube, specific supralaryngeal airways may give some level of protection. First, the Combitube has been shown to protect from regurgitation by virtue of its open-faced esophageal lumen and esophageal cuff (27). The classic LMA, although never designed to protect from regurgitated stomach contents, has an excellent track record of use in full-stomach patients (33, 34). A recent advancement in the family of LMAs is the Proseal-LMA, which adds a gastric drain. Although it is not yet proven to protect the airway from regurgitated material, studies in cadavers (34) and clinical anecdotes have indicated this.

Both the Combitube and LMA do an excellent job of preventing gastric insufflation compared with the face mask (35), the Combitube doing a better job in this regard (36).

Despite the adequacy of supralaryngeal techniques that isolate the lower airway from the alimentary tract, protection from the aspiration of regurgitated gastric contents should only be considered adequate when a cuffed tracheal tube is in place: Therefore, one should immediately consider awake intubation in the patient whom the clinician considers a "full stomach" or at high risk of aspiration and in whom intubation likely will be difficult. In this case, the evaluation has reached the cognitive equivalent of "cannot intubate" and "should not ventilate." The Combitube and LMA do add a degree of flexibility in this regard by virtue of the previously outlined protection from aspiration. For example, if the judgment is made that a patient requires awake tracheal intubation but is unable to cooperate with this technique (e.g., pediatric, mentally retarded, or inebriated patients), these devices may allow an alternative and provide a limited degree of safety in deviating from the AAA to DAA pathway.

Will the Patient Tolerate an Apneic Period? Once the clinician is satisfied that supralaryngeal ventilation can be used and that there is no aspiration risk that would contraindicate use of these devices, the clinician could proceed with the induction of anesthesia with the plan that, if direct laryngoscopy and tracheal intubation fail, ventilation by face mask or other supralaryngeal device should be possible and safe. Unfortunately, the incidence of "cannot ventilate" by any means—including face mask, LMA, or other supralaryngeal device—is not known. Therefore, the clinician has to be wary that in the event that the patient cannot be ventilated by any means and cannot be rapidly intubated, oxyhemoglobin desaturation may occur. Controlled human studies as well as computer simulations demonstrate that an adequately preoxygenated, healthy adult should maintain oxyhemoglobin saturation for 5–9 mins after the onset of apnea (37–39). A healthy child should tolerate 2–4 mins of apnea after preoxygenation, depending on the age and weight (40). Factors such as obesity, pregnancy, illness, and inadequate preoxygenation will contribute to premature oxyhemoglobin desaturation. Because an induction dose of thiopental is expected to cause 30–60 secs of apnea, an induction dose of propofol is expected to cause >60 secs of apnea, and muscle relaxation with succinylcholine is expected to cause 4–7 mins of

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apnea, the clinician must consider whether the patient will tolerate this apneic period if the clinician's answer to question 3 (can supralaryngeal ventilation be used?) was incorrect. If the clinician determines that the patient may not tolerate an error in judgment in question 3, then the anticipated difficult airway root point of the DAA should be chosen. If, on the other hand, it is judged that the patient will tolerate the apneic period, the AAA recommends that the clinician proceed with the routine induction of anesthesia, ensuring the immediate availability of those supralaryngeal devices that were taken into consideration when answering question 3 in the affirmative.

SUMMARY

When the patient comes to the operating room, it is with the expectation that a pathological process will be treated. Unfortunately, the anesthetic that is administered to facilitate and enable surgery has the potential to complicate the clinical course by introducing a new set of morbidities. Chief among these must be considered respiratory compromise. A systematic approach to the decision to control the airway is the first step in reducing complications. The AAA strives to give the anesthesiologist a stepwise approach to decision making in the evaluation of the airway. Although it may be impossible to anticipate every airway that is difficult to manage, the vast majority can be managed safely if the clinician approaches all patients in a rational manner. The choice of the difficult airway tools employed is generally less important than the decisions that must be made regarding a) the need for airway control; b) the ease of laryngoscopy; c) the ability to use supralaryngeal ventilation; d) the aspiration risk; and e) the tolerance that the particular patient may have to judgment error. Although it is recognized that violation of the AAA pathways may at times be required, the anesthesiologist must make sure that this deviation is in the best interest of the patient.

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