



Airway Problems and New Solutions for the Obstetric Patient

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Anesthesia-related complications are the sixth leading cause of pregnancy-related maternal mortality in the United States. Difficult or failed intubation following induction of general anesthesia for cesarean delivery remains the major contributory factor to anesthesia-related maternal complications. Although the use of general anesthesia has been declining in obstetric patients, it may still be required in selected cases. Because difficult intubation in obstetric anesthesia practice is frequently unexpected, careful and timely preanesthetic evaluation of all parturients should identify the majority of patients with difficult airway and avoid unexpected difficult airway management. © 2003 by Elsevier Inc.

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Introduction

Obstetric anesthesia is considered by many to be a high-risk subspecialty of anesthesia practice that is laden with clinical challenges and medicolegal liability. Anesthesia-related complications are the sixth leading cause of pregnancy-related maternal mortality in the United States.¹ Difficult or failed intubation following induction of general anesthesia for cesarean delivery remains the major contributory factor to anesthesia-related maternal complications.^{2,3} In 1997, Hawkins *et al.*¹ published the results of the first national study of anesthesia-related maternal mortality in the United States for the periods 1979 to 1984 and 1985 to 1990; the overall anesthesia-related death rate declined from 4.3 per million live births in the first triennium (1979–1981) to 1.7 per million in the last (1988–1990). The majority of deaths (82%) in this study occurred during cesarean delivery. Fifty-two percent of the deaths resulted from complications of general anesthesia. Because general anesthesia-related mortality has remained stable between 1979 and 1990, the authors concluded that the decrease in overall anesthesia-related death rate was a result of a decrease in complications of regional anesthesia. Thus, for the period from 1979 to 1984, the risk ratio of general anesthesia mortality to regional anesthesia mortality was 2.3, and for the period from 1985 to 1990, it was 16.7. Although the American Society of Anesthesiologists' (ASA) difficult airway algorithm and several modifications have been published, specific problems of the obstetric patient, to date, have not been addressed.^{4–8}

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The Obstetric Airway in Perspective: Pregnancy-Induced Anatomical and Physiologic Changes

The pregnant patient is at greater risk for airway management problems and difficult intubation than the nonpregnant patient.^{5,9} Anatomical and physiologic factors that place the pregnant patient at increased risk for airway management complications and difficult intubation include pregnancy-induced generalized weight gain and, particularly, increase in breast size, respiratory tract mucosal edema, decreased functional residual capacity (FRC), and increased oxygen consumption.

It is not uncommon for the parturient to gain 20 kg or more during pregnancy. Obesity has been reported to further increase the risk of anesthetic complications in parturients.⁴⁻⁵ A high body mass index (BMI) has been associated with an increased risk of airway management problems including difficult intubation.¹⁰ Additionally, the obstetric literature indicates that parturients with a high BMI are at increased risk for cesarean section. Weight gain and uterine enlargement leads to a decreased FRC, which hastens the onset of hypoxemia during periods of hypoventilation or apnea.¹¹ Pregnancy results in significant increase in breast size. In the supine position, the enlarged breasts tend to fall back against the neck, which can interfere with insertion of the laryngoscope and intubation. Therefore, use of a short-handled laryngoscope has been widely recommended in obstetric patients.¹⁰ In addition, placing the patient in the sniffing position helps keep the laryngoscope handle away from the breasts.

It has been well established that total body water significantly increases in pregnancy due to the effect of increased progesterone levels.¹⁰ Healthy parturients typically have generalized body edema, although this edema is not clinically significant in the majority of these patients. Vascular engorgement of the respiratory tract during pregnancy leads to edema of the nasal and oral pharynx, larynx, and trachea.^{10,12,13} These physiologic changes often cause difficulty with nasal breathing, increased incidence of nasal bleeding, and voice changes. These changes in the nasal mucosa may, however, result in bleeding at the time of airway manipulation or nasogastric tube placement. Laryngeal edema may inhibit the passage of standard size endotracheal tube (ETT), despite adequate vocal cord visualization at laryngoscopy and require a smaller internal diameter tube size. Furthermore, tongue enlargement may make it difficult to retract the tongue into the mandibular space during direct laryngoscopy.

Increased maternal metabolic requirements combined with fetal metabolic needs and increased maternal respiratory requirements result in increased maternal oxygen consumption. In approximately 12% to 15% of parturients at term, the gravid uterus may compress the vena cava and aorta in the supine position, causing decreased venous return, decreased cardiac output, blood pressure, and uterine blood flow. Therefore, pregnant women should not be allowed to assume the supine position.

Pregnant patients have an elevated gastric acid content, with decreased pH, and reduced function of the gastroesophageal sphincter secondary to the mechanical and hormonal effects of pregnancy. Consequently, all laboring parturients should be assumed to have full stomachs and are at increased risk for aspiration of gastric contents.⁹ Anesthesia should always be induced with cricoid pressure to decrease the risk of regurgitation of gastric contents in the pharynx.² Denitrogenation with the administration of 100% oxygen is mandatory before rapid-sequence induction of general anesthesia.¹⁰

General Remarks

Although the use of general anesthesia has been declining in obstetric patients, it may still be required in selected cases. Thus, it is essential for the anesthesiologist to perform a proper preanesthetic evaluation and identify the factors predictive of difficult intubation. Several authors have attempted to quantitate the contribution of a combination of specific risk factors to airway management difficulty in the pregnant patient;¹⁴ however, none of them has been widely accepted.

It is hoped that careful attention to the ASA Practice Guidelines for Management of Difficult Airway,⁷ the ACOG Committee Opinion entitled "Anesthesia for Emergency Deliveries",¹⁵ and the availability of new ancillary airway management tools such as Laryngeal Mask Airway™ (LMA; The LMA Co., Inc., San Diego, CA) and Combitube™ (Tyco-Kendall Co., Mansfield, MA) will result in an increase in safety of general anesthesia in obstetric population. The ACOG's Committee Opinion states that obstetricians should obtain an early consultation with an anesthesiologist in high-risk patients, particularly the morbidly obese or those with a potentially difficult airway, so that the anesthesiologist can properly prepare the patient for anesthesia.¹⁵ ACOG's Committee Opinion recommends that strategies can be developed to minimize the need for emergency induction of general anesthesia in women for whom it would be hazardous. For those patients at risk for cesarean delivery, consideration should be given to the planned placement of an epidural in early labor, with confirmation that the catheter is functional.¹⁵

Management

The Recognized Difficult Airway

There is a subset of patients who have certain anatomical features that should indicate that endotracheal intubation *via* conventional means is very likely to be difficult if not impossible.¹⁰ Certain anatomical features (very large breasts and heavy chest wall, large tongue, no teeth and sunken cheeks, fixed head or neck flexion, massive jaw, upper airway mass) may also render mask ventilation difficult or impossible. If there is any doubt regarding the ability to maintain airway patency during general anesthesia, alternative methods of anesthesia should be considered.¹⁰ Options include the use of regional anesthesia,

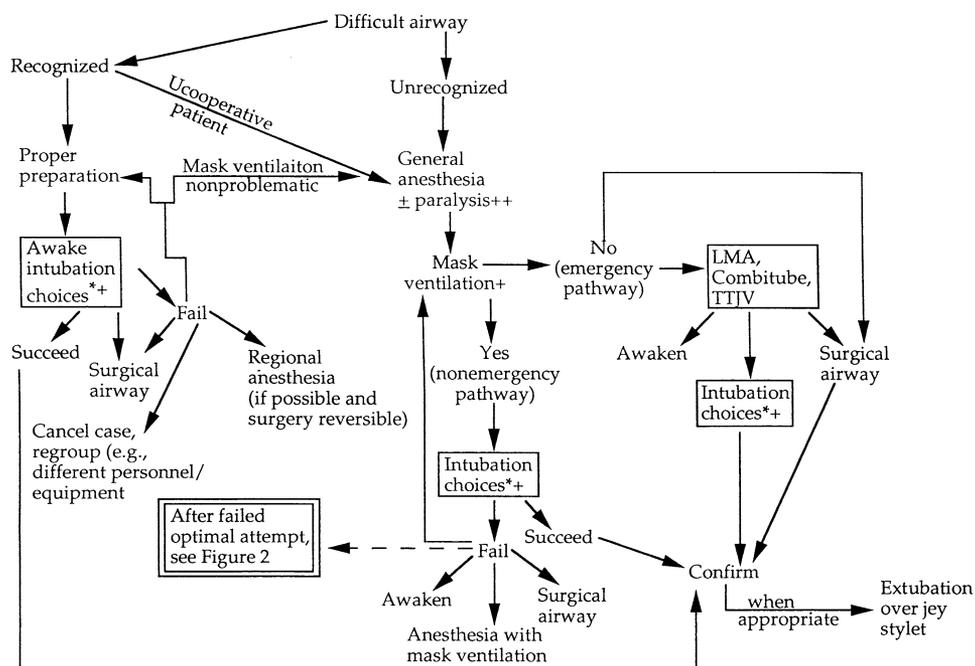


Figure 1. The ASA Difficult Airway Algorithm. (From: Benumof JL. Management of the difficult airway. *Anesthesiology* 1991;75:1087-110; Practice Guidelines for Management of the Difficult Airway. A Report by the ASA Task Force on the Management of the Difficult Airway. *Anesthesiology* 1993; 78:597-602; Benumof JL: The Laryngeal Mask Airway and the American Society of Anesthesiologists Difficult Airway Algorithm. *Anesthesiology* 1996; 84:686-699.) +Always consider calling for help) e.g., technical, medical, surgical etc.) when difficulty with mask ventilation and/or tracheal intubation is encountered. ++ Consider the need to preserve spontaneous ventilation. *Nonsurgical tracheal intubation choices consist of laryngoscopy with a rigid laryngoscope blade (many types), blind orotracheal or nasotracheal technique, fiberoptic/stylet technique, retrograde technique, illuminating stylet, rigid bronchoscope, percutaneous dilational tracheal entry. See above for a complete discussion of these intubation choices.

local infiltration anesthesia, or, if there is adequate time, an awake intubation followed by induction of general anesthesia (Figure 1).

Regional Anesthesia

Regional anesthesia is the best choice for cesarean section in most cases of anticipated difficulty with endotracheal intubation.² Either spinal or epidural anesthesia is acceptable providing there is no contraindication. Both techniques allow the mother to be awake and minimize the potential for acid aspiration. However, the anesthesiologist should understand that regional anesthesia itself does not solve the problem of a difficult airway, anticipate potential complications (e.g., failed anesthesia, total spinal anesthesia), and be fully prepared (both mentally and technically) to administer general anesthesia.^{2,3,5,9,10}

Nausea and vomiting is a common complication during administration of regional anesthesia for cesarean section. In addition, in the event of a failed block, general anesthesia may be required. Therefore, all patients should receive pharmacologic prophylaxis against acid aspiration.^{5,10} All patients should also receive supplemental oxygen during administration of spinal or epidural anesthesia for cesarean section. The increased maternal frac-

tional inspired oxygen concentration (FIO₂) increases fetal oxygenation.¹⁶

Local Anesthesia

If a patient with a difficult airway requires urgent cesarean section, and if there is a contraindication to the use of spinal or epidural anesthesia, local anesthetic infiltration can be used as the primary anesthetic technique.¹⁷⁻¹⁹ However, local anesthetic infiltration is a technique rarely used today for cesarean section in developed countries. It is more often used in undeveloped countries with an inadequate number of experienced anesthesia providers and/or limited anesthesia equipment and supplies.¹⁰

Awake Intubation Followed by General Anesthesia

When the anesthesiologist anticipates that management of the airway will be difficult, a very safe option is to secure the airway with an ETT while the patient remains awake.^{2,3,5,9,10} Although awake intubation can be somewhat time-consuming, there are several compelling reasons to perform the procedure in a patient with a recognized difficult airway: 1) the natural airway is better maintained in an awake patient; 2) the presence of normal

muscle tone helps maintain the natural separation of the upper airway structures, which facilitates the identification of anatomical landmarks; and 3) induction of general anesthesia and muscle paralysis results in anterior movement of the larynx, which impedes visualization of the larynx during direct laryngoscopy.²⁰

Successful awake endotracheal intubation requires proper preparation of the patient.^{5,6,10} Ideal preparation results in a quiet and cooperative patient and a larynx that is nonreactive to physical stimuli. The first step is psychological preparation. The patient who knows what is going to happen is usually more receptive and cooperative. Minimal monitoring should include the use of an automated blood pressure cuff, pulse oximetry, and an electrocardiogram (ECG). Supplemental oxygen should be administered at all times during the procedure.^{5,6,10}

Administration of an anticholinergic drying agent (*e.g.*, glycopyrrolate) allows better application of local anesthetic spray to the airway mucosa, improves visualization, and inhibits vagal reflexes.¹⁰ Glycopyrrolate is poorly transferred across the placenta, and its maternal administration does not result in a detectable fetal hemodynamic response.²¹ Judicious use of intravenous (IV) sedation helps relieve anxiety and increases the pain threshold in an awake patient. This situation facilitates patient tolerance of the application of the topical anesthetic as well as the performance of nerve blocks and endotracheal intubation. It is essential to titrate analgesic and sedative drugs carefully so as to maintain continual verbal communication between the anesthesiologist and the patient.²¹ Midazolam is the benzodiazepine recommended for these purposes; however, it is highly unionized and very lipophilic, and its fetal/maternal ratio is 0.76 at 15 to 20 minutes after maternal administration.²¹ However, unlike those of other benzodiazepines, the ratio of midazolam decreases rapidly. To date, no adverse fetal effects have been reported.²¹ The patient should remain rational, alert, and responsive to commands. Respiratory depression during the application of local anesthetic is less likely to occur if the patient remains awake and alert. In addition, limiting the amount of sedation decreases the risk of neonatal depression.

Topical anesthesia is the primary anesthetic for awake intubation.^{5,6,10} In some patients, topical anesthesia is the only anesthetic needed, provided sufficient time is allowed to anesthetize all portions of the airway adequately. If the nasal route is chosen, the nasal mucosa should also be sprayed with a vasoconstrictor and the nasal passage dilated with an ever-enlarging series of soft nasopharyngeal airways that are liberally coated with lidocaine ointment.^{5,6,10} The pressure receptors that elicit the gag reflex at the root of the tongue are submucosal in location. Therefore, topical anesthesia may not uniformly provide adequate blockade of these pressure receptors,¹⁰ and bilateral blockade of the lingual branch of the glossopharyngeal nerve (*i.e.*, cranial nerve IX) may be required.²²⁻²⁶ However, a research group has recently questioned its efficiency and superiority to topical anesthesia for awake laryngoscopy.²⁷

Blockade of the internal branch of the superior laryngeal nerve represents a second upper airway nerve block that is a helpful supplement to the use of topical anesthesia and block of the lingual branch of the glossopharyngeal nerve.¹⁰ This block consists of application of local anesthetic superficial or deep to the thyrohyoid membrane between the superior lateral cornu of the thyroid cartilage and the inferior lateral margin of the cornu of the hyoid bone. (The nerve pierces the membrane at this point and can be blocked on either side of the membrane.^{28,29}) This block, performed in conjunction with a lingual nerve block, often allows direct laryngoscopy using a Miller blade.

Transtracheal administration of local anesthetic (administered through the cricothyroid membrane) may also be performed easily.¹⁰ Unfortunately, this technique is associated with a low but serious risk of bleeding from disruption of an aberrant thyroid vessel.³⁰ This block is usually unnecessary if topical anesthesia has been applied properly.

There is some controversy as to the appropriate use and extent of local anesthesia for awake intubation in a patient with a presumed full stomach. Block of the superior larynx may theoretically allow food and water to enter the trachea during deglutition. Some researchers have recommended that airway anesthesia be limited to the transtracheal injection of local anesthetic in patients with a full stomach.³¹ However, Cooper and Watson²⁹ reported no complications with the use of topical cocaine spray combined with lingual and superior laryngeal nerve blocks to facilitate awake intubation in patients with a full stomach. Subsequently, Duncan³² used topical anesthesia from the tongue to the trachea; none of the patients from that study vomited or aspirated.

In our experience, the key to avoiding aspiration is to avoid oversedation; *i.e.*, there is a low-risk of aspiration of gastric contents in an awake, alert, and rational patient, regardless of the extent of topical anesthesia.¹⁰ Lower esophageal tone is maintained if the patient is not oversedated. Moreover, in the event of impending vomiting, an awake patient can help turn her head and body to the side, open her mouth for suctioning, delay the next inhalation, and produce a cough (provided the trachea is not completely anesthetized).^{33,34} Management priorities must be established for the parturient with a difficult airway; obviously, successful tracheal intubation should be the first priority and it is absolutely essential that the patient be adequately locally anesthetized. The risk of aspiration in a well locally anesthetized, but awake patient, can be further minimized by IV administration of an H₂-receptor antagonist and metoclopramide and oral administration of a nonparticulate antacid before beginning the procedure.¹⁰ H₂-receptor antagonists block histamine receptors on the oxyntic cells, thus decreasing gastric acid production. When given IV, an H₂-receptor antagonist begins to take effect in as little as 30 minutes, but 30 to 60 minutes are required for maximal effect.³⁵ Metoclopramide is a procainamide derivative that is a cholinergic agonist peripherally and a dopamine receptor antagonist centrally. A 10-mg IV dose of metoclopramide increases

lower esophageal sphincter tone and reduces gastric volume by increasing gastric peristalsis.³⁵ Metoclopramide can have a significant effect on gastric volume in as little as 15 minutes.³⁵ Prior administration of opioids antagonizes the effects of metoclopramide. Metoclopramide crosses the placenta, but researchers have reported no significant effects on the fetus.³⁵ In some patients, it may also be appropriate to insert an orogastric or nasogastric tube to decompress the stomach before beginning the procedure.

Once the upper airway has been anesthetized adequately, there are numerous ways to intubate the trachea. The choice of technique depends on several factors, including the skill experience of the laryngoscopist and the urgency of cesarean section.

Direct Laryngoscopy

Of all intubation techniques, direct laryngoscopy results in the most noxious stimulation for the patient. Thus, it requires the best patient preparation. However, most well prepared patients easily tolerate direct laryngoscopy.¹⁰

If the larynx is poorly visualized with direct laryngoscopy, several aides may be used to facilitate intubation. The Eschmann malleable stylet (a gum elastic bougie) is a guiding stylet that is placed blindly around the epiglottis into the trachea. After the stylet is placed in the trachea, the ETT is threaded over the stylet and the stylet is removed. Cahen³⁶ has recommended use of a laryngotracheal anesthesia (LTA) cannula for this purpose. The tip of the LTA cannula is inserted through the Murphy eye at the tip of a well-lubricated ETT. Direct laryngoscopy is performed, and the tip of the LTA cannula is inserted through the vocal cords. The ETT is then advanced over the LTA cannula into the trachea, and the cannula is removed. With either of these techniques, orientation of the Murphy eye at 12 o'clock will facilitate the passage of the ETT over the stylet into the trachea.^{37,38}

Blind Nasal Intubation

Blind nasal intubation is much less stimulating than direct laryngoscopy, and it may be worth a try in patients who are breathing spontaneously. If it is attempted, a small (6.0 to 6.5 mm) ETT should be used.¹⁰ Unfortunately, pregnant women have hyperemic nasal mucosae. Instrumentation of the nose entails the risk of nasal and nasopharyngeal bleeding. Such bleeding can be substantial in pregnant women and can compromise subsequent efforts at direct or fiberoptic laryngoscopy.¹⁰

Fiberoptic Laryngoscopy

The flexible fiberoptic intubation has become the "gold standard" for airway management and the most useful aid to awake intubation in the parturient with known difficult airway.³⁹⁻⁴¹ Fiberoptic laryngoscopy is much less stimulating than direct laryngoscopy and/or blind nasal intubation, and it can be performed either po or nasally. It is also considered safer and less traumatic than nasal intubation, which may cause significant bleeding in some parturients.

The major impediments to success are significant amounts of blood or secretions and lack of patient preparation and cooperation. The fiberoptic bronchoscope/laryngoscope can suction only small amounts of secretions. We prefer to insufflate oxygen through the suction port. The insufflation blows secretions away from the tip of the bronchoscope, which facilitates optimal visualization of the anatomical structures of the airway. Insufflation of oxygen through the suction port also serves as a defogging mechanism, and it provides supplemental oxygen, which results in a higher FIO₂ for the patient. Immersion of the tip of the bronchoscope into warm saline (or antifog solution) before insertion into the patient also decreases fogging.¹⁰

Extension of the cervical spine represents the optimal position for performance of fiberoptic laryngoscopy. Extension tilts the larynx anteriorly and lifts the epiglottis off the posterior pharyngeal wall. Numerous devices are available to facilitate fiberoptic intubation. The oral fiberoptic intubation guides⁴²⁻⁴⁴ are rigid, hollow, oropharyngeal conduits that are designed to bring the tip of the fiberoptic bronchoscope close to the laryngeal aperture without requiring much endoscopic skill.

An appropriately sized, well-lubricated ETT is placed on the bronchoscope before its insertion. Once the fiberoptic bronchoscope is passed into the trachea, the ETT is threaded off the fiberoptic bronchoscope, the bronchoscope is withdrawn, the ETT adaptor is reattached, and the ETT is connected to the breathing circuit.⁴⁵ Even with the fiberoptic bronchoscope in the correct position, the ETT may not always follow easily into the trachea for one of the following reasons:⁴⁵ 1) a large, stiff ETT may displace the thin fiberoptic bronchoscope into the esophagus if the ETT is aligned posteriorly. 2) The right arytenoid or right vocal cord may obstruct the ETT as it is passed off the fiberoptic bronchoscope. This problem is corrected by withdrawing the tube slightly and then rotating it 90 degrees counterclockwise so that the bevel tip and Murphy eye are at 12 o'clock. 3) If the fiberoptic bronchoscope exits the ETT *via* the Murphy eye, the fiberoptic bronchoscope may enter the trachea, but it is impossible to slide the ETT off the fiberoptic bronchoscope into the trachea.

After the ETT has been passed over the fiberoptic bronchoscope into the trachea, the distance between the carina and the tip of the ETT should be noted to ensure proper positioning of the tube.

Retrograde Intubation

Retrograde intubation techniques have been used for several decades with good success,^{46,47} especially in patients with maxillofacial trauma.⁴⁸ Although this technique has been of value in the management of the difficult airway in the past, today it has little, if any value for the obstetric patient.

The Bullard Laryngoscope

The Bullard laryngoscope (Circon ACMI, Stamford, CT) functions as an indirect fiberoptic laryngoscope.⁴⁹⁻⁵¹ A fiberoptic bundle is positioned along the length of the

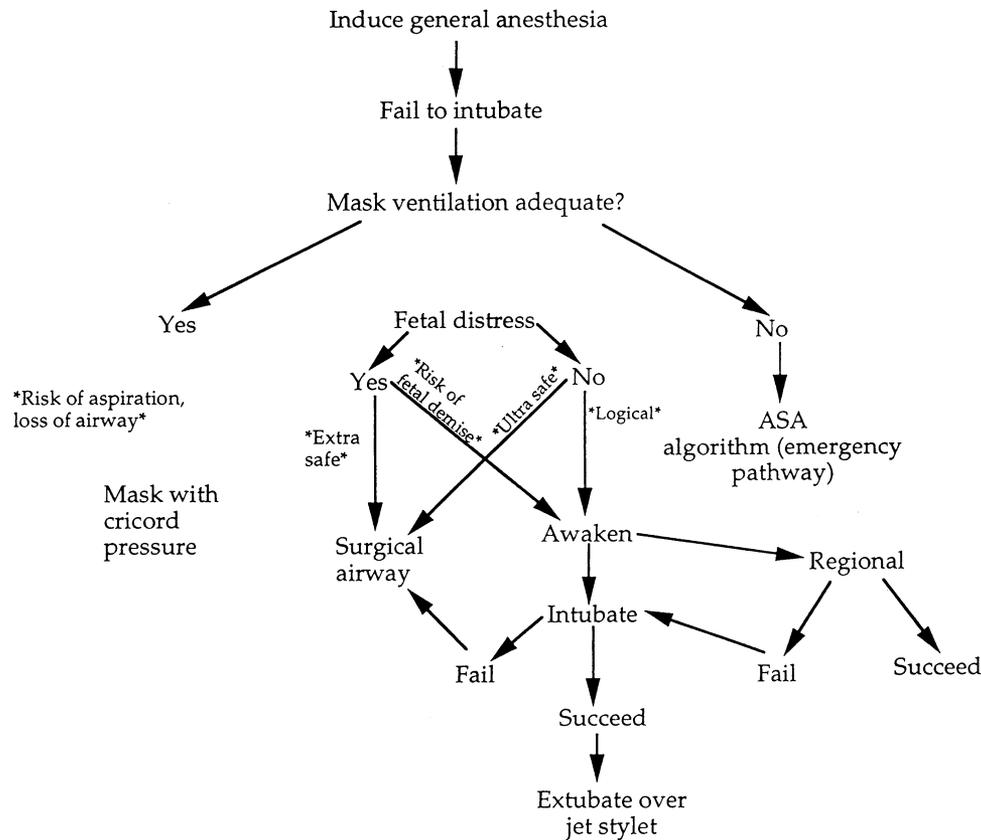


Figure 2. Supplement to the difficult airway management algorithm, with special reference to the presence or absence of fetal distress. This algorithm includes options in the management of a recognized difficult airway in an uncooperative patient or in a cooperative patient with dire fetal distress. *Denotes implications of this choice.

posterior aspect of the blade, which gives the endoscopist a view at the end of the blade. Some researchers have reported that this laryngoscope renders visualization of the larynx much easier.^{49,50} Because visualization of the larynx is based on the presence of a fiberoptic bundle at the tip of the blade, positioning of the head in the usual sniffing position is unnecessary; this situation is advantageous when manipulation of the head is contraindicated (e.g., cervical spine fracture). A considerable amount of practice is necessary to become skilled in the use of this laryngoscope, as is true for the other new blades. Cohn *et al.*⁵¹ described the only report of the use of Bullard laryngoscope for emergency airway management in a morbidly obese parturient.

The Unrecognized Difficult Airway

Ideally, a skilled anesthesia provider will perform a complete, preanesthetic airway evaluation in every laboring woman. In some cases (e.g., dire fetal distress), the obstetrician will ask the anesthesiologist to provide anesthesia as rapidly as possible.^{2,15} In other cases, maternal conditions (e.g., hemorrhage, coagulopathy) contraindicate the administration of regional anesthesia. However, even in an emergency situation, there should be time to perform an

airway examination. In most of these cases, the anesthesiologist will opt for rapid-sequence induction of general anesthesia. In the event that intubation is not successful, the anesthesiologist should have a well-formulated plan in mind, and the appropriate equipment and supplies should be immediately available to implement that plan.^{5,10} The algorithm that details emergency airway management, with special reference to the presence or absence of fetal distress is presented in *Figure 2*.

Practice Guidelines for Obstetrical Anesthesia developed by the ASA (section VI: Management of Complications, paragraph 2: Equipment for Management of Airway Emergencies. Park Ridge, IL: American Society of Anesthesiologists) state that the availability of equipment for the management of airway emergencies is associated with reduced incidence of maternal complications.⁵² Practice Guidelines recommend that labor and delivery units have equipment and personnel readily available to manage airway emergencies. Basic airway management equipment should be immediately available during the provision of regional anesthesia. In addition, portable equipment for difficult airway management should be readily available in the operative area of labor and delivery units.⁵²

If the anesthesiologist is confronted with an unexpected difficult intubation, it is important to take inven-

tory of what has been tried and which other manipulations can be tried in accordance with fetal well-being, hemodynamic stability, and the respiratory status of the patient.^{2,3,5,9,10} For example, if there is no fetal distress, the patient is hemodynamically stable, there is adequate gas exchange *via* mask, and only one anesthesiologist has attempted intubation with one type of blade, time permits optimizing the chances of successful intubation. This plan should include 1) repositioning the patient into a better (*e.g.*, sniffing) position, 2) applying external laryngeal pressure (*e.g.*, over the thyroid cartilage), 3) using a different laryngoscope blade (length and/or type), and 4) having another anesthetist attempt intubation.^{2,3,5,9,10} An optimal attempt at intubation should be achieved by the third or fourth attempt. With respect to mask ventilation, if only one person has manipulated the jaw and held the mask seal and no oropharyngeal or nasopharyngeal airways have been used, it is appropriate to place an oropharyngeal and/or nasopharyngeal airway and institute two-person jaw thrust/mask seal.^{5,6,10} However, if the patient is hypotensive and hypoxic with clusters of multifocal premature ventricular contractions, regardless of how many attempts at intubation have been made, the patient's clinical status mandates aggressive airway control.¹⁰ It needs to be reemphasized that anesthesia-related complications are the sixth leading cause of pregnancy-related maternal mortality in the United States, and difficult or failed intubation constitutes the major contributory factor to these complications.^{1,2} Therefore, every effort should be made to prevent airway management-related maternal morbidity and mortality. Aggressive airway control may be achieved by either optimal two-person mask ventilation or insertion of an LMA or Combitube, or institution of transtracheal jet ventilation (TTJV) or emergency cricothyrotomy.¹⁰

The Patient Who Cannot Be Intubated but Can Be Ventilated by Mask with no Fetal Distress

When the anesthesiologist is unable to intubate the trachea of an anesthetized patient, it is essential to try to maintain gas exchange by mask ventilation between intubation attempts.² During positive-pressure mask ventilation, maintenance of cricoid pressure is mandatory. All the intubation techniques previously described for the awake patient can be used in the unconscious patient, without modification. However, with every intubation attempt, the amount of laryngeal edema and bleeding likely will increase.^{2,10} Therefore, if there is no new atraumatic manipulation that can be tried quickly (*e.g.*, better sniffing position, application of external laryngeal pressure, new laryngoscope blade, new technique, more experienced laryngoscopist and ventilation by mask is still possible, it is prudent to cease attempts to intubate the trachea and either awaken the patient, perform the fiberoptic intubation of the trachea, or perform a tracheostomy or cricothyrotomy (right hand side of *Figure 2*). If the patient is awakened, assisted mask ventilation should continue while an assistant maintains cricoid pressure.^{2,5,9,10} After awak-

ening the patient, options include awake intubation, regional anesthesia, and local infiltration anesthesia. Establishment of a surgical airway is an acceptable alternative because emergence may be accompanied by progressive difficulty with adequate mask ventilation (*e.g.*, secondary to increased secretions, edema, or airway reactivity). It is very apparent from the ASA Closed-Claim Study that death following failed intubation can be due to subsequent failure to effectively ventilate the patient by facemask.⁵³

The Patient Who Cannot Be Intubated but Who Can Be Ventilated by Mask with Fetal Distress Present

In the presence of fetal distress, management decisions are more problematic. The first option is to awaken the patient.^{2,10} This conservative yet difficult decision will probably preserve the mother's life, but it may result in the demise of the fetus. The second option is to perform a tracheostomy or cricothyrotomy before the ability to ventilate the lungs *via* a mask is lost. The third option is to continue anesthesia *via* mask ventilation while an assistant maintains cricoid pressure (*i.e.*, the "failed intubation drill"). The use of the LMATM may be tempting in this situation because the device frees the anesthetist's hands. However, the hazards of failed insertion and subsequent maternal desaturation must be carefully considered.^{2,9,10} Additionally, it must be noted that the LMA does not provide effective protection from aspiration.

Failed Intubation Drill

Tunstall⁵⁴ proposed a failed intubation drill in the parturient, which was later revised by Rosen⁵⁵ and is now common practice in the United Kingdom. The objective of the failed intubation drill is to achieve spontaneous ventilation and oxygenation *via* mask, without aspiration.^{54,55}

Spontaneous Versus Controlled Ventilation

When the decision is made to proceed with general anesthesia by mask, the anesthesiologist must decide whether to allow the patient to breathe spontaneously or to control ventilation by maintaining muscle relaxation. In the failed intubation drill, ventilation is controlled initially and is followed by resumption of spontaneous ventilation.^{54,55} Unfortunately, an absence of muscle relaxation may complicate attempts to proceed with surgery and may result in a difficult, traumatic delivery of the fetus. Maintenance of muscle relaxation may facilitate not only operative delivery but also positive-pressure ventilation (PPV) *via* mask. On the other hand, if muscle relaxation is maintained, the option of allowing the patient to resume spontaneous ventilation and to awaken are lost.¹⁰ Muscle relaxation and immobility can be achieved through deep inhalational anesthesia, but at this depth of anesthesia, spontaneous ventilation is unlikely to result in adequate ventilation and oxygenation, especially in a pregnant

woman in the Trendelenburg position (which results in increased pressure on the diaphragm).

The Patient Who Cannot Be Intubated or Ventilated by Mask

Included in the failed intubation drill is the option that "if oxygenation is difficult, allow suxamethonium to wear off and let the patient wake up," bearing in mind that "the airway may be difficult to maintain."⁵⁵ Mask ventilation was found to be laborious in 0.02% of pregnant patients. It is evident that not only pregnancy itself, but also other factors (*i.e.*, distorted anatomy of the airway) are the causes for difficult ventilation in pregnancy, although airway edema resulting from hormonally induced fluid retention during pregnancy may be primarily responsible for difficult ventilation and/or intubation in pregnancy.^{2,5,9,10} Edema of the face and neck should alert the anesthesiologist to the possibility of difficult ventilation and intubation in the parturient. However, rarely it is impossible to ventilate *via* mask or intubate the trachea. Unless an alternative plan is immediately available, death will rapidly ensue. Several alternative ventilation methods have been described that can be instituted quickly and have a low risk-to-benefit ratio.¹⁰ These methods include 1) intentional intubation and occlusion (obstruction) of the esophagus with a standard ETT, 2) insertion of an esophageal-tracheal Combitube, 3) insertion of LMATM, and 4) institution of TTJV. A fifth option, not practiced routinely by anesthesiologists, is an emergent cricothyrotomy or tracheostomy.

The CombitubeTM

The esophageal-tracheal Combitube (ETC) is a plastic, twin-lumen tube with an outer diameter of 13 mm.⁵⁶ One lumen resembles an ETT, and the other resembles an esophageal obturator airway (EOA), with the distal end closed. A 100-mL proximal pharyngeal balloon is located on the ETC, so when the ETC is properly positioned, the pharyngeal balloon will fill the space between the base of the tongue and the soft palate. The inflated proximal balloon serves to seal the oral and nasal cavities.^{56,57} Just distal to the pharyngeal balloon but proximal to the level of the larynx are perforations in the esophageal lumen. A smaller, 10 mL distal cuff, similar to an ETT cuff, serves to seal either the esophagus or trachea when inflated. The ETC is inserted blindly, and in terms of ability to ventilate the patient, it does not matter whether the ETC enters the trachea or the esophagus.⁵⁶ Most likely, the ETC will enter the esophagus, and the patient can be ventilated *via* the esophageal lumen perforations. If the ETC enters the trachea, the patient can be ventilated directly *via* the tracheal lumen. In contrast, if an EOA enters the trachea, ventilation is not possible, and extubation of an EOA from a tracheal position leaves the airway unprotected.^{56,57}

In most reports, the ETC provided adequate ventilation within 15 to 30 seconds of insertion. The ETC allows for adequate ventilation while preventing aspiration of gastric

contents.⁵⁶ Use of the ETC has resulted in adequate ventilation and oxygenation under diverse clinical conditions (such as failed intubation during surgery, cardiopulmonary resuscitation, respiratory failure in the intensive care unit).⁵⁶ In the esophageal position, the unused tracheal lumen can be connected to a suction device to aspirate gastric fluids. Thus far, only one case report documenting the use of the ETC in the parturient has been published.⁵⁷ Wissler⁵⁷ described the use of CombitubeTM for airway management in the parturient undergoing cesarean section. Interestingly, Tunstall and Geddes⁵⁸ described the successful use of a somewhat similar device, the esophageal gastric tube airway (EGTA), following failed intubation in emergency cesarean section.

The Laryngeal Mask AirwayTM: Use as an Airway

The LMA is now a recognized part of the ASA difficult airway algorithm and should be a part of every obstetric anesthesiologist's armamentarium in managing the difficult airway in the parturient.^{5,8,59,60}

One of the reasons why the LMA works well as a routine airway is that exact positioning is not crucial for a clinically acceptable airway; the usual fit of the LMA around the larynx, as assessed by using flexible fiberoptic endoscopy, radiologic investigation, and nuclear magnetic resonance imaging, is somewhat variable.⁸ Nevertheless, in 94% to 99% of patients, there is no difficulty with ventilation and the airway is ultimately judged to be clinically acceptable (although proper position may require two insertion attempts; see below). Indeed, because the LMA works well as a routine airway/ventilatory device in most patients, it is not surprising that the LMA has been found to be a life-saving emergency airway/ventilatory device in obstetric patients undergoing emergency cesarean section who could not be ventilated using a bag and conventional mask, and whose trachea could not be intubated conventionally.⁶¹⁻⁶⁶

The routine use of the LMA for airway management can be associated with a number of problems. These problems consist of a clinically unacceptable nonpatent airway; the requirement for multiple insertion attempts in a small percentage of patients; aspiration of gastric contents; and suboptimal PPV. The exact incidence of each of these problems must depend, to some extent, on the insertion technique and skill of the operator.^{60,61,64,65} Inadequate anesthesia may cause all of these problems, and therefore a basic requirement for the safe use of the LMA is an adequate depth of anesthesia. The most serious problem is that in 0.4% to 0.6% of anatomically normal patients, placement of the LMA is clinically inadequate due to either back folding of the distal cuff, occlusion of the glottis by the distal cuff, complete back folding of the epiglottis, or by a 90- to 180-degree rotation of the mask around the long axis. There have been no reports of failure to correctly place or ventilate through the LMA in patients requiring this device in a cannot-ventilate/cannot-intubate situation.¹⁰ Consequently, in such a situation, a quick, first-try insertion of the LMA is an acceptable maneuver, except when local pathology in the pharynx or

larynx precludes a reasonable chance of proper placement and/or even limited gas exchange. If insertion of the LMA does not affect gas exchange quickly, then TTJV should be immediately instituted or a surgical airway immediately created.⁶⁻⁸

Han *et al.*⁶⁰ prospectively studied the use of LMA for elective cesarean section in 1,067 consecutive ASA physical status I and II patients preferring general anesthesia. The authors concluded that the LMA is effective and probably safe for elective cesarean section in healthy, selected patients when managed by experienced LMA users.

The ProSeal Laryngeal Mask Airway (PLMA) is a new laryngeal mask device with a modified cuff and a drainage tube designed to isolate the airway from the digestive tract.⁶⁷ The design should also improve the seal with the larynx. Evans *et al.*⁶⁷ assessed insertion characteristics, airway seal pressures, hemodynamic response to insertion, ease of gastric tube placement, gastric insufflation, and postoperative sore throat associated with the use of PLMA in 300 anesthetized adults. They concluded that the PLMA is a reliable airway management device that can give an effective glottic seal in paralyzed and nonparalyzed patients. The device allowed the easy passage of a gastric tube, caused a minimal hemodynamic response to insertion, and an acceptable incidence of sore throat.⁶⁷ Cook *et al.*⁶⁸ conducted a randomized, cross-over, comparison study of the PLMA with the classic LMA in 180 nonparalyzed anesthetized patients and concluded that the PLMA allowed PPV more reliably than the classic LMA.⁶⁸ It is believed that the PLMA's ability to allow PPV more reliably than the classic LMA might have some advantages in obstetric anesthesia.

The LMA: Use as a Conduit for Tracheal Intubation

There are numerous reports, primarily letters to the editor, of the LMA as an airway conduit for either the blind passage of an ETT or an intubating stylet, or for the passage of a flexible fiberoptic bronchoscope (FOB).⁶⁹⁻⁷² In view of the manner in which the LMA usually seats around the larynx, it is obvious that when the LMA has a perfect central position (45% to 60% of the time) any one of the blind insertions has some chance of success.^{10,68} The greater the degree of noncentral location of the LMA over the larynx, the less is the likelihood of achieving a successful blind intubation. In addition, the unsuccessful (off-center) insertion of a rigid object through a noncentral LMA may result in laryngopharyngeal injury. When blind tracheal intubation was attempted through the LMA in a series of patients thought to have normal anatomy, there was a 26% to 97% failure rate on the first attempt and a 10% to 79% overall failure rate with an ETT, and there was an 18% to 70% overall failure rate with the intubating stylet.⁸

The use of cricoid pressure further decreases the chance of passing an ETT blindly through the LMA into the trachea for two reasons. First, when cricoid pressure is applied before the LMA is placed, the pressure prevents the tip of the LMA from fully occupying the 3.5-cm length of the hypopharynx behind both the arytenoid and cricoid

cartilages. Thus, with cricoid pressure, the LMA may be wedged in the hypopharynx, but it can only occupy the 1.5 cm of the hypopharynx behind the arytenoid cartilages and is therefore 2 cm more proximal than usual. Variable obstruction to the passage of the LMA by cricoid pressure may explain why the concomitant use of cricoid pressure has resulted in widely variable success in simply inserting the LMA from a low of 15% to a high of 85% to 90%.⁸ If cricoid pressure does impede passage of the LMA, then the resultant, more proximal than usual, off-center location of the LMA should only further decrease the success rate of blind intubation through the LMA.

The placement of an LMA in the obstetric patient who can be ventilated *via* conventional mask while cricoid pressure is being continuously applied would have little benefit and might induce vomiting and aspiration.⁶⁹⁻⁷² A reasonable alternative between the competing concerns of continuously maintaining cricoid pressure in a patient at risk for aspiration and failure to properly insert the LMA during cricoid pressure is to momentarily release cricoid pressure as the distal tip of LMA reaches the hypopharynx.⁶⁴ This action maximizes the chance of correct LMA placement while minimizing risk of aspiration. Once the LMA is *in situ*, it probably does not interfere with the efficacy of cricoid pressure.⁷³

Second, the wedging into and subsequent full inflation of the cuff of an LMA in a hypopharynx that has been constricted by the application of cricoid pressure causes the plane of the laryngeal aperture to tilt approximately 40 degrees anteriorly around the fulcrum of the inflated LMA distal cuff. It seems likely that it would be more difficult for a blindly inserted intubating device to enter an aperture that is in a plane 40 degrees off the perpendicular to the insertion pathway than an aperture that is in the plane perpendicular to the insertion pathway.^{61,62,64,65} Failure to enter the trachea with an intubating stylet or ETT (both of which are semirigid) may result in periglottic trauma. In summary, blindly attempting to intubate through an LMA may be unsuccessful and even harmful, especially in the presence of cricoid pressure.^{8,10}

Conversely, passage of a fiberoptic bronchoscope through the LMA has a much greater chance of success and is nearly 100% successful in most series.⁸ A 6 mm internal diameter (ID) cuffed ETT (a nasal RAE tube [Mallinckrodt, Saint Louis, MO]) is most suitable because of both very adequate length and widespread availability) may be passed over the FOB and through the shaft of sizes 3 and 4 LMA and a 7 mm ID cuffed ETT may be passed over the FOB and through the shaft of a size 5 LMA. If a larger ETT is desired, the LMA and the 6- or 7-mm inner diameter cuffed ETT may be exchanged for a larger ETT over a jet stylet.⁶ The lungs can be continuously ventilated around the FOB but within the ETT by passing the FOB through the self-sealing diaphragm of a bronchoscopy elbow adaptor; the distal and proximal ends of the bronchoscopy elbow adaptor are connected to the ETT and the ventilatory apparatus, respectively. When a 4-mm outer diameter FOB is combined with a 6-mm inner diameter ETT, the space available for ventilation around the FOB corresponds to a 4.5 mm ID ETT.

Transtracheal Jet Ventilation

Percutaneous insertion of a large-gauge IV catheter through the cricothyroid membrane is simple, quick, and relatively safe in most patients.^{74,75} This technique represents an effective method to facilitate TTJV in the desperate situation in which the patient cannot be intubated or ventilated by mask. Compared with emergency surgical cricothyrotomy or tracheostomy, establishment of percutaneous TTJV is quicker, simpler, and more efficacious.^{74,75} In other words, most anesthesiologists can insert a needle into the trachea and aspirate air faster than anyone can cut through the cricothyroid membrane, spread the cricothyroid membrane with a hemostat, insert a conventional ETT through the hole of the membrane, and then inflate the cuff, even if all of these surgical steps proceeded smoothly. Numerous reports have documented the use of TTJV to prevent life-threatening gas exchange problems in patients who are difficult to ventilate or intubate during general anesthesia.^{74,75} This technique permits continuous, uninterrupted ventilation and oxygenation while allowing unhurried access to secure the patient's airway.

First, the cricothyroid membrane is palpated with the neck of the patient extended. Then a 14- or 16-gauge IV catheter is used to puncture the cricothyroid membrane with the needle pointed 30 degrees caudad from the perpendicular. A 20 mL syringe is then attached to the catheter, and aspiration of air confirms its transtracheal location. (Use of a smaller syringe may result in removal of the plunger from the syringe barrel with vigorous aspiration; thus, we recommend the use of a 20-mL syringe.) The needle stylet is then withdrawn (at least partially), and the catheter is advanced into the trachea until the hub of the catheter is at the skin line.^{74,75} The TTJV catheter should be reaspirated to reconfirm intratracheal lumen location. The hub of the IV catheter is then connected to a TTJV system. A designated individual should be responsible for holding the hub of the TTJV catheter secure to the skin. During TTJV, it is important to maintain the natural airway by using bilateral jaw thrust and oropharyngeal and nasopharyngeal airways to allow for exhalation of inspired gas and to prevent air trapping and lung hyperinflation.

To achieve adequate ventilation and oxygenation, the TTJV system must have a sufficient high-pressure oxygen source (approximately 50 psi) that can drive oxygen through noncompliant tubing and the relatively small IV catheter. Many TTJV systems have been described,³⁰ and four high-pressure sources are considered acceptable. These include a jet injector powered by 1) central wall pressure, 2) a high-flow tank regulator, 3) a low-flow tank regulator, and 4) selected anesthesia machines (*e.g.*, use of the common gas outlet *via* activation of the flush valve).^{76,77} Use of central wall pressure or a high-flow tank regulator as a power source necessitates down-regulation to 30 psi to avoid barotrauma.⁷⁸ Commercially manufactured systems include a 0 to 50 psi inline regulator. Reducing the pressure to 30 psi will still allow these power sources to provide adequate tidal volumes (V_T) and

minute ventilation (V_E) through 14- to 20-gauge catheters at lung compliances that range from normal (100 mL/cm H_2O) to noncompliant (30 mL/cm H_2O).⁷⁶ The smallest V_E of 12 L/min through a 20-gauge catheter at a lung compliance of 30 mL/cm H_2O will still allow partial if not total ventilatory support in the vast majority of clinical situations.

Percutaneous or Open Surgical Cricothyrotomy and Tracheostomy

Performance of a hurried, open surgical cricothyrotomy or tracheostomy under suboptimal conditions is questionable and may be dangerous. Some authors⁷⁹ advocate percutaneous surgical cricothyrotomy or tracheostomy as an alternative to open surgical cricothyrotomy or tracheostomy. These physicians argue that percutaneous surgical cricothyrotomy is just as safe, quick, and easy to perform as percutaneous needle cricothyrotomy (TTJV). Toy and Weinstein⁸⁰ first described percutaneous tracheostomy (and cricothyrotomy) in 1969. The technique evolved from the premise that the percutaneous technique allows a functional airway to be obtained more rapidly than the standard tracheostomy dissection method. Several techniques have been described. These techniques typically include insertion of a needle into the trachea and subsequent dilation of the needle track to accommodate a functional airway. Recently, several kits have become commercially available.⁸¹⁻⁸³ Leinhardt *et al.*⁸⁴ compared the Ciaglia Cook and the Schachner Rapitrac kits with conventional tracheostomy. A higher proportion of patients in the Rapitrac group had complications, including tube misplacement and tube cuff air-leak secondary to cuff puncture. The authors concluded that the Cook system of percutaneous tracheostomy is a simple, rapid, and safe alternative to conventional tracheostomy.

There is some question as to who should perform this procedure. Most surgeons should be able to perform this operation, but it is unclear whether anesthesiologists, who are already skilled in vascular access using the Seldinger technique, should be trained to perform percutaneous tracheostomy. The same considerations apply to open (*e.g.*, scalpel) cricothyrotomy, which should be considered the failed-airway resuscitation maneuver of last resort. Surgical assistance should always be summoned or available if these procedures are performed by nonsurgeons. The call for surgical assistance must occur early in the management of the difficult airway so that assistance will be available at the appropriate time.

Summary

Difficult or failed intubation following induction of general anesthesia for obstetric emergencies is a major contributory factor to anesthesia-related maternal morbidity and mortality.^{1,5,7,9,10} In obstetric anesthesia, difficult intubation is frequently unexpected.⁸⁵ Careful and timely preanesthetic evaluation of all parturients should identify the majority of parturients with difficult airway and avoid

unexpected/emergent difficult airway management.¹⁰ The American College of Obstetricians and Gynecologists recognizes hazards of general anesthesia (particularly if administered in emergency situation), and recommends early consultation with an obstetric anesthesiologist in all high-risk parturients. Such early communication should encourage timely decision-making and improve the cooperation between the obstetricians and obstetric anesthesiologists. ACOG also advocates early administration of epidural analgesia in all high-risk parturients, particularly the morbidly obese and those with a potentially difficult airway.¹⁵

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