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Review article

Management of the difficult and failed airway in obstetric anesthesia

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Abstract
Difficulty with airway management in obstetric patients occurs infrequently and failure to secure an airway is rare. A failed airway may result in severe physical and emotional morbidity and possibly death to the mother and baby. Additionally, the family, along with the medical and nursing staff, may face emotional and financial trauma. With the increase in the number of cesarean sections performed under regional anesthesia, the experience and training in performing endotracheal intubations in obstetric anesthesia has decreased. This article reviews the management of the difficult and failed airway in obstetric anesthesia. Underpinning this important topic is the difference between the nonpregnant and pregnant state. Obstetric anatomy and physiology, endotracheal intubation in the obstetric patient, and modifications to the difficult airway algorithms required for obstetric patients will be discussed. We emphasize that decisions regarding airway management must consider the urgency of delivery of the baby. Finally, the need for specific equipment in the obstetric difficult and failed airway is discussed. Worldwide maternal mortality reflects the health of a nation. However, one could also claim that, particularly in Western countries, maternal mortality may reflect the health of the specialty of anesthesia.

Key words Difficult airway · Failed airway · Obstetric anesthesia

Introduction

In 1847 James Young Simpson (1811–1870) pioneered the concept of anesthesia and pain relief in childbirth. This idea, however, did not win immediate acceptance, owing to a major concern about "safety." Within 10 years, John Snow (1813–1858) succeeded in lifting theoretical restrictions on the use of obstetric anesthesia through his meticulous approach, superb clinical skills, and his renown from anesthetizing Queen Victoria [1]. In the 1950s, obstetric anesthesiologists recognized the need for the use of a cuffed endotracheal tube, as a result of Mendelson's documentation of the problems of the pulmonary aspiration of gastric contents [2]. Later in the twentieth century, the specialty of obstetric anesthesia recognized the morbidity and mortality associated with difficult and failed intubation in obstetrics [3]. This led to the development of a "Failed intubation drill" by Tunstall [4] and the improvement of local anesthetic agents and techniques [5]. Although obstetric anesthesia is, at times, influenced by fashions and trends, safety remains constant as the most important and central aspect of obstetric anesthesia. The maternal mortality rate is regarded as a direct indicator of the health-care of a nation. Estimated global maternal mortality is more than 500 000 per year [6]. Nearly 99% of this mortality occurs in developing countries and 1% in developed ones. In the United States, an article by Hawkins et al. [7] estimated that for the 1988–1990 triennium the maternal mortality was 1.7 per million live births and during the same period the England and Wales maternal mortality was also 1.7 per million maternities. The most recent data, from the report on Confidential Enquiries into Maternal Deaths in the United Kingdom, demonstrated that there were seven cases of anesthetic-related maternal deaths during the 2000–2002 triennium and four of these were directly due to poor airway management [8,9].

A 2003 analysis of the American Society of Anesthesiologists (ASA) Closed Claims database revealed that 635 of the 5300 cases (12%) were associated with obstetric anesthesia care; 71% of these 635 cases were associated with cesarean section [10]. The most common claim was maternal death (22%), which was more frequently associated with general anesthesia than regional anesthesia. Critical events involving the respiratory system were the most common precipitants of injury in

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Table 1. Incidence of difficult and failed obstetric airway

Study	Intubation measurement	Obstetric incidence	General incidence
Cormack and Lehane [12]	Difficult: laryngoscopic view, grade 3	1:2000	
Yeo et al. [16]	Difficult: laryngoscopy, grade 3, 4	1:46 (2.1%) Gynecologic 1:56 (1.8%)	1:50 (2.0%)
Lyons [13]	Failed	1:300 (0.33%)	
Samsoon and Young [15]	Failed	1:283 (0.35%)	1:2230
Rocke et al. [14]	Failed	1:750 (0.13%)	
Benumof [11]	Cannot ventilate Cannot intubate		0.001%–0.02%

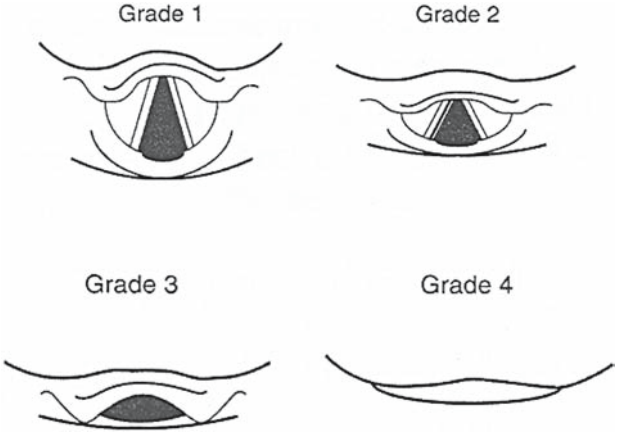

Fig. 1. Illustrates a difficult airway defined by the laryngeal view on laryngoscopy [15]. Reprinted with permission

these cases. Respiratory system problems included difficult intubation, aspiration, esophageal intubation, inadequate ventilation/oxygenation, bronchospasm, airway obstruction, inadequate fractional inspired oxygen (F_iO_2), seizures, and problems with equipment.

Published incidences of difficult and failed obstetric airway are detailed in Table 1 [11–16]. The Cormack and Lehane laryngoscopy grade may be used to classify the difficulty of intubation, and the grades are presented in Fig. 1. The contribution of airway difficulties to maternal morbidity and mortality has heightened the awareness of the need for expert airway management in obstetrics.

Anatomy and physiology of the obstetric airway

An understanding of the anatomical and physiological changes in pregnancy aids the management of the problems associated with the obstetric difficult airway [17].

The effects of estrogen and increased blood volume contribute to edema and friability of the upper airway mucosa. This change may cause nasal congestion and an increased risk of mucosal bleeding, especially with airway manipulation. Laryngeal edema can cause difficulty in passing the endotracheal tube. There have been a number of reports describing difficulties with endotracheal intubation due to facial and laryngeal edema in patients with pre-eclampsia and eclampsia. Smaller-size endotracheal tubes should be used in obstetrics [18,19].

As it enlarges, the gravid uterus displaces the diaphragm cephalad and increases the abdominal circumference, while the hormonal changes induced by pregnancy increase the subcostal angle of the ribs. These factors result in the diaphragm and intercostal muscles contributing equally to the tidal volume. Anatomical changes lead to a 20% decrease in functional residual capacity (FRC), which can be decreased by another 25% when changing from the sitting to the supine position. This decrease is in the residual volume and the expiratory reserve volume. Pain and fatigue of labor can exacerbate the change in FRC. The decrease in FRC will accelerate the onset of oxygen desaturation during hypoventilation and apnea.

There is no significant alteration in total airway resistance during pregnancy. Chest wall compliance is decreased but lung compliance is unchanged. The net effect of these changes is a 50% increase in the oxygen cost of breathing. Ventilatory drive is increased during pregnancy, giving rise to hyperventilation. Progesterone is responsible for ventilatory stimulation but the specific mechanism is unknown [20]. Both oxygen consumption and carbon dioxide production are increased by 20%–40% at term.

There is a delay in gastric emptying and a decrease in gastric pH during pregnancy. In addition, there is an increase in intragastric pressure associated with an incompetent gastro-esophageal sphincter. Heartburn occurs in 20% of pregnant women during their first trimester, and in more than 70% of pregnant women during their third trimester [21]. A "full stomach" should always be a concern in this group of patients.

While some of the changes associated with morbid obesity are similar to those seen in pregnancy, the two conditions are different and as such require different

solutions. For example, because adipose tissue has a lower metabolic rate compared to other tissues the increase in oxygen consumption seen in obesity is proportionally less than the increase in weight. Oxygen consumption expressed per kilogram is less in the obese patient than in the parturient [22]. In contrast, the decreased FRC and increased oxygen consumption seen in the obstetric patient is more reminiscent of the neonate than of the obese patient.

Endotracheal intubation in the obstetric patient

Indications

Apart from endotracheal intubation for elective cesarean section under general anesthesia and postpartum procedures, e.g. tubal ligation under general anesthesia, all other intubations are performed as emergencies. During emergency endotracheal intubation, a full airway assessment may not be performed and the availability, appropriateness, and function of induction drugs, monitors, and other equipment may not have been checked. Preexisting and pregnancy-related diagnoses, maternal hypovolemia, or coagulopathy may not be fully appreciated. Skilled help may not be readily available. These factors mean that establishing an airway in the emergency setting poses a higher risk than in an elective setting.

General anesthesia for cesarean section, often in the setting of fetal distress, is the commonest indication for endotracheal intubation in the obstetric patient. However, a failed regional technique, high spinal or high epidural block, local anesthetic toxicity, cardiac arrest, and respiratory and neurological emergencies may each result in the need for endotracheal intubation. The purported advantages of general anesthesia include a faster onset and less hemodynamic disturbance. However, regional techniques are advocated by some experts who believe that they are associated with better outcomes than general anesthesia, especially with respect to the baby [23]. A recent Cochrane systematic review of regional versus general anesthesia for cesarean section included elective and urgent cases. The techniques did not differ in the resultant umbilical arterial pH. Results from the analysis of umbilical venous pH favored the regional group, but the numbers were small and the values were above the cutoff for acidosis. Although the reviewers found that the mean Apgar scores at 1 and 5 min favored the regional group, when Apgar scores of 6 or less were analyzed there was no difference between the regional and general anesthetic groups [24].

Obstetric airway assessment

An adequate airway assessment prior to all anesthesia and analgesia procedures on the labor floor is essential. A complete assessment can be performed in approximately 1–2 min. Table 2 outlines a scheme for airway assessment, while Fig. 2 demonstrates the Mallampati classification [25]. Some advocate that all patients on the labor floor should undergo an airway assessment examination on admission. The American College of Obstetricians and Gynecologists recommends that the obstetric care team should "be alert" for the general anesthesia risk factors, and if present, specialist consultation should be obtained, and consideration be given for the placement of an epidural catheter in early labor [26]. In assessing the obstetric airway it is important to take into account maternal congenital abnormalities; for example, Noonan syndrome, Pierre Robin syndrome, hereditary telengiectasis, and neurofibromatosis. Important acquired maternal conditions include preeclampsia, morbid obesity, and obstructive sleep apnea. Both congenital and acquired conditions may contribute to the difficult obstetric airway.

Table 2. Essentials of airway assessment

1	Facial edema
2	Obesity and short neck
3	Neck flexion and extension-atlanto-occipital extension
4	Mandibular space-thyromental distance
5	Mouth opening
6	Dentition—protruding maxillary incisors, missing teeth
7	Oropharyngeal structures—Mallampati classification

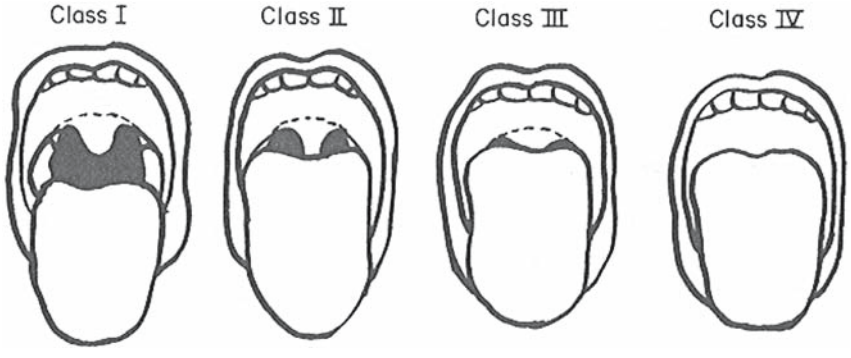

Fig. 2. Mallampati classification [15]. Reprinted with permission

Unfortunately, only a few obstetric studies have evaluated airway assessment prospectively. Rocke et al. [14] performed an airway assessment in 1500 parturients undergoing emergency and elective cesarean section under general anesthesia. This group discovered a strong correlation between oropharyngeal structures and the laryngoscopy view and difficulty at intubation. Multivariate analysis demonstrated that failure to visualize oropharyngeal structures, and the presence of a short neck, receding mandible, and protruding maxillary incisors were associated with a less favorable laryngoscopy view. It is important to note that one of the endpoints in this study was difficult intubation, as judged by a scoring system developed by the authors. In this study there were only two cases of failed intubation, giving an incidence of 1:750 or 0.13%. Yeo et al. [16] demonstrated that the Mallampati score was predictive of a difficult intubation. Their endpoint was the laryngeal view. However, in their study, intubation difficulty was observed even in some patients with Mallampati grade 2 views.

Preparation for intubation

A prophylactic regimen to neutralize and minimize stomach acid is usually administered in an effort to decrease the risk of pulmonary aspiration of gastric contents in pregnant women. The nonparticulate antacid sodium citrate (0.3 M) and the H2-receptor antagonist ranitidine are administered to neutralize the stomach's acidity and prevent further gastric acid production. Metoclopramide will facilitate gastric emptying and raise the gastro-esophageal sphincter tone [27–29]. Although these are "time-honored practices" the endpoints used to measure the efficacy are usually secondary. Because of the low incidence of aspiration pneumonitis, it is difficult to prove that these medications decrease the incidence or improve the outcome of the complication.

While it may seem obvious, it is vital that all essential monitoring, drugs, and equipment must be checked and ready prior to any regional or general anesthetic procedure in the obstetric operating room. Emergency airway adjuncts, such as oral and nasal airways, endotracheal tube stylets, gum elastic bougie, light wand, and a fiberoptic intubating device should be readily available.

Endotracheal intubation

Paying close attention to all aspects of the performance of endotracheal intubation is especially important in obstetric anesthesia, and in some cases modification of the technique may be required [17]. The patient needs to be correctly positioned. The neck needs to be flexed at the cervico-thoracic junction and extended at the atlanto-occipital joint. Properly positioned pillows help to exaggerate the position by bringing the anatomical axes into line while optimizing and improving success [30]. At least 3 min of inspiring 100% oxygen with an anesthesia closed-face mask is the ideal for the denitrogenation technique. When time is limited, four deep breaths (DB), i.e., vital-capacity breaths of 100% oxygen (4 DB/30 s) or 8 DB in 60 s (8 DB/60 s) can be used [31,32].

General anesthesia is usually induced intravenously with thiopental, propofol, or ketamine. Cricoid pressure should be in position at the onset of induction and fully applied as the patient is induced. There may be difficulty inserting the scope due to poor positioning of the patient, the size of the chest wall and breasts, and improperly positioned cricoid pressure. Surprisingly, there has been no study suggesting which laryngoscope blade is optimal. At present the recommendation is that the blade with which the operator is most familiar should be used. Following endotracheal intubation, confirmation is necessary by quantitative and qualitative measurement of end-tidal CO_2.

Stress and the obstetric airway

Psychological stresses involved in the difficult airway in obstetrics have been largely ignored. Obstetrics is one of the few areas of medicine where there is a "true" emergency. There are two lives at risk, those of the mother and the baby. Not uncommonly, the anesthesiologist is an infrequent practitioner in the labor ward and is not completely comfortable with obstetric practice or the pathophysiological changes of the mother and baby. Sometimes the practitioner can be one of the most junior of the anesthesia care team. The access to skilled help can be limited. There has also been a decrease in the number of cesarean sections performed under general anesthesia, leading to a decrease in experience, both at the consultant and trainee level [33]. All these factors precipitate stresses that have the potential to influence the behavior of the obstetric anesthesiologist at the most crucial time—during the management of the airway. Although the impact of the psychological stress has been ignored, difficult airway algorithms and education regarding the cognitive and technical skills required for the difficult airway help to alleviate these stresses and prepare the anesthesiologist in managing the difficult obstetric airway.

Difficult airway algorithms and failed intubation drills

ASA difficult airway algorithm

The ASA difficult airway algorithm has standardized the approach to the difficult airway [34]. Such stand-

ardization aims to minimize the morbidity and mortality associated with the difficult airway and aids in education and research. However, the ASA difficult airway algorithm needs to be adapted for obstetric patients.

Significant differences between the obstetric and ASA algorithms include:

1. Most obstetric cases are emergency rather than elective
2. Considerations related to maternal, uterine, and fetal physiology
3. In obstetrics, both the mother and the fetus need to be assessed and considered
4. Spontaneous breathing is preferred in the nonobstetric patient

In the same manner as for the ASA difficult airway algorithm, initial assessments are required and subsequent decisions are made based on these assessments. The initial assessments include evaluation of the maternal airway and fetal status. The clinician needs to decide whether the airway is difficult, as an expected difficult airway is easier to manage than an unexpected difficult airway. If one is faced with an "expected difficult airway," the next decision is whether to perform a regional technique versus an awake-intubation technique, and if an awake-intubation is chosen, whether to perform a surgical technique versus a non-surgical technique.

Cardiac arrest

As difficult or failed intubation may lead to cardiac arrest, the potential for maternal cardiac arrest must be assessed. Aspiration and lung injury will exacerbate the hypoxia of the difficult and failed airway, further increasing the potential for cardiac arrest. Protocols for cardiopulmonary resuscitation in pregnancy advocate perimortem cesarean delivery within 5 min of cardiac arrest [35]. In the difficult or failed intubation, earlier cesarean section may aid resuscitation.

Obstetric difficult and failed airway algorithms

There are a number of difficult and failed obstetric airway algorithms. Most are complicated, aiming to cover all contingencies [30,36,37]. The nature and quality of evidence for these algorithms is not stated and they are based mainly on a compilation of case reports. Importantly, there is no evidence of effectiveness. The development of a simpler algorithm may increase its ease of use and allow a determination of the algorithm's effectiveness. The desire for the development of a simple algorithm has led to the introduction of "drills" to be used in the event of a failed-intubation in an obstetric patient. A 17-year review of a failed-intubation drill at St. James's University Hospital in the United Kingdom illustrated some of the benefits of this approach [38]. Of 5802 cesarean sections between 1987 and 1994, there were 23 (0.4%) failures to intubate the trachea. The algorithm used was simple and specific for unexpected failed intubation. Most of the failures were for emergency situations. Eighteen patients were allowed to waken and regional techniques utilized. Manual ventilation was difficult in 7 patients and impossible in 2. Four patients had a laryngeal mask airway (LMA) inserted. Using the LMA in this situation, the lungs were difficult to ventilate in two episodes and impossible to oxygenate on one occasion.

No anesthesia or obstetric anesthesia association or society has developed evidence-based guidelines for the obstetric difficult airway or failed obstetric intubation. Approaches to the expected and unexpected difficult airway are outlined in Figs. 3 and 4, respectively. The guidelines are intended to promote discussion of airway management techniques.

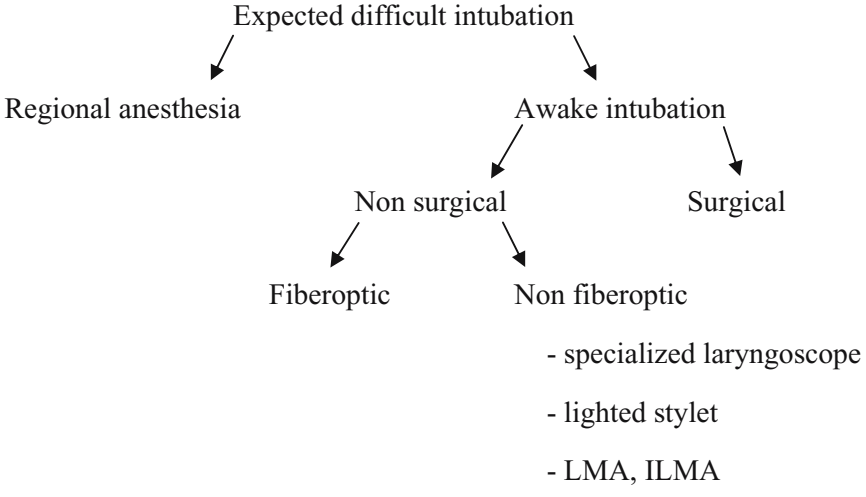

Fig. 3. Algorithm for expected difficult intubation. *LMA*, laryrigeal mask airway; *ILMA*, intabating LMA

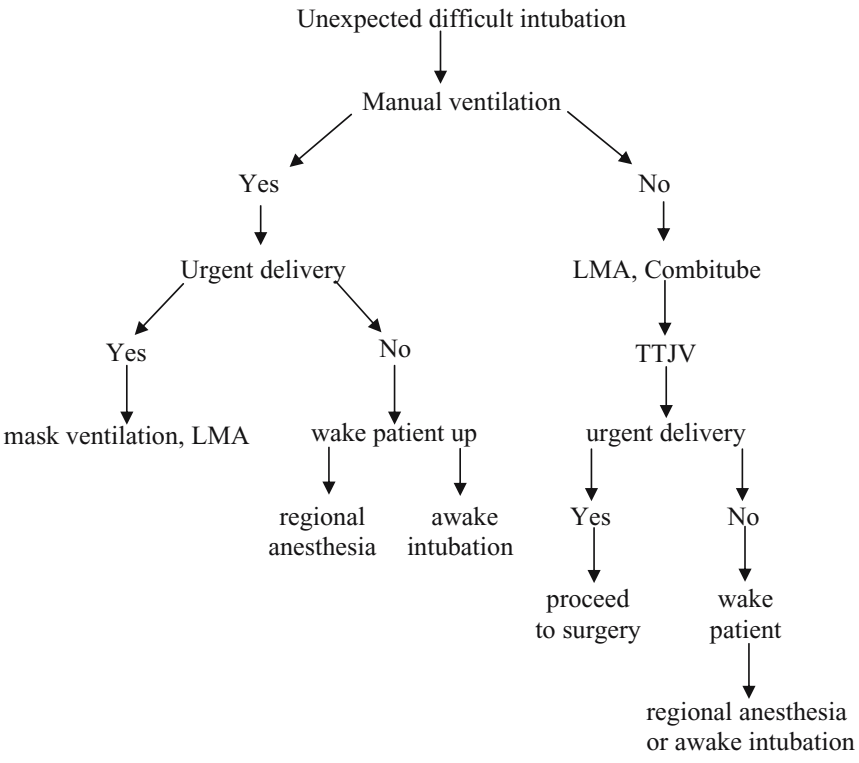

Fig. 4. Algorithm for unexpected difficult intubation. *TTJV*, transtracheal jet ventilation. Combitube (Kendall-Sheridan Catheter, Argyle, MA, USA)

Expected difficult intubation

Once the assessment has determined that the airway is expected to be difficult, a decision must be made between the use of regional anesthesia for the patient or an awake intubation followed by general anesthesia. If awake intubation is decided upon, a surgical or non-surgical technique must be chosen. For the obstetric difficult airway an awake surgical airway is of limited utility. Most likely the technique would be of benefit in a parturient who has suffered upper airway trauma or when an obvious pre-existing airway problem exists. There have been two case reports describing insertion of tracheotomy prior to delivery [39,40]. In one case the patient subsequently underwent cesarean section under regional anesthesia with the tracheotomy used as a backup. In the other case, the parturient underwent an elective tracheotomy due to her past medical history of difficult and failed intubation attempts.

Regional anesthesia and the difficult obstetric airway

Regional anesthesia is usually selected in the case of an airway that is expected to be difficult. In nonemergency obstetric situations, the choice of a regional technique is dependent on anesthesiologist and patient preference and characteristics. In emergency situations, when rapid attainment of surgical conditions is required, general anesthesia may be chosen. However, the need to swiftly attain surgical anesthesia is not a contraindication to a regional technique in the hands of an experienced anesthesiologist. The only absolute contraindications to regional anesthesia in obstetrics are patient refusal and coagulopathy. This is especially important in the case of an anticipated difficult airway, where a regional technique may be advantageous. Although the literature suggests that outcomes are equivalent after regional or general anesthesia in emergency situations, there is no literature to support the optimal regional technique.

Although "conventional wisdom" endorses a regional technique in the expected difficult airway, complications or failure of the regional technique may make it necessary to intubate the trachea. Thus, a backup plan is necessary, with the availability of appropriate equipment. Hawksworth and Purdie [41] described a patient with a failed combined spinal epidural technique who failed an endotracheal intubation, and was then woken up and underwent an awake fiberoptic intubation. This is one of many case reports illustrating the potential difficulties of regional anesthesia. When deciding on the regional technique, it is important to select the technique that minimizes the potential for airway, cardiac, and respiratory emergencies for the individual parturient.

Awake intubation techniques

Local anesthesia and the upper airway

Local anesthesia plays an important role in the success of an awake intubation technique. It is necessary to provide adequate upper airway anesthesia before every awake intubation technique. The use of selective nerve blocks or direct application of local anesthetic agents will provide adequate anesthesia of the upper airway. The hormonal changes in pregnancy increase the sensitivity of peripheral nerves to local anesthetic agents [42]. In pregnancy, the upper airway membranes have increased vascularity, increasing the uptake and decreasing the duration of action of the local anesthetic. Thus, these two factors may balance out. However, it is important to be vigilant for local anesthetic toxicity. The local anesthetic agent prilocaine may induce a dose-related methemoglobinemia. The fetus may be more susceptible because of immature reductase enzyme pathways that predispose it to methemoglobinemia from oxidizing agents such as metabolites of prilocaine [43].

Awake nonfiberoptic intubation techniques

There are many techniques for awake nonfiberoptic intubation. These vary from basic to more modern techniques. Different-sized Macintosh and Miller laryngoscope blades, as well as specialized laryngoscopes with fiberoptic light sources of different shapes can be used. Airway adjuncts, such as stylets, intubating bougies, and external manipulation of the larynx may all play a role in aiding intubation. The lighted stylet can also be used as a means to secure an "awake" airway without need for use of a fiberoptic bronchoscope. Although blind nasal intubation can be used, bleeding from the vascular membranes may further complicate the already difficult intubation.

The LMA, intubating laryngeal mask airway (ILMA), or the ventilating LMA can be used for awake airway management. The ILMA is probably the preferred choice, as a definitive cuffed airway can be readily introduced. There are case series and case reports describing the use of the ILMA and one case report describing the use of the LMA to facilitate awake endotracheal intubation in obstetric patients with difficult airways [44–46]. There are no reports of the use of the ventilating LMA for awake airway management in obstetrics.

Awake fiberoptic intubation

Fiberoptic scopes may be nonflexible or flexible. Of the nonflexible scopes, only the Bullard has been reported to have been used in an awake obstetric patient with a difficult airway [47]. Flexible fiberoptic intubation techniques are popular for the expected difficult airway, especially in the parturient. Fiberoptic techniques require expensive equipment that may not be easily portable and may have steep training curves. The fiberoptic devices should allow the delivery of supplemental oxygen, as hypoxia is a common complication during these procedures.

There are multiple case reports describing the success of fiberoptic bronchoscope-guided intubation in both the expected and the unexpected difficult obstetric airway. These reports describe the use of the fiberscope in patients predicted to have a difficult airway based on preoperative evaluation, as well as in those patients in whom obvious defects were present, including congenital facial abnormality, goiter, and odontoid fracture [48–53]. Some anesthesiologists prefer awake fiberoptic intubation over regional anesthesia in the predicted difficult airway parturient [54]. They argue that the use of regional anesthesia in a patient with an expected difficult airway does not solve the airway problem, and complications from regional anesthesia can lead to an emergency difficult airway situation. However, the failure and complication rates of awake fiberoptic intubation in the parturient are unknown. Potential complications include hypoxia, trauma to the laryngeal structures, and bleeding from the vascular membranes, especially if the nasal route is chosen. Difficulty in passing the endotracheal tube may be seen in pre-eclampsia, where patients may have laryngeal edema.

Retrograde intubation technique

A retrograde intubation technique can be utilized in the expected or unexpected difficult obstetric airway. When an awake fiberoptic intubation technique has failed, bleeding and edema may result, increasing the difficulty of subsequent attempts. A retrograde technique may be useful in this scenario [55]. Once the guidewire has been passed through the cricothyroid membrane and has exited the mouth or nose, it can be threaded up the suction channel of the fiberoptic scope. The fiberoptic scope is then advanced along the guidewire under direct vision through to the trachea.

Unexpected difficult intubation

With a nonobstetric unexpected difficult airway, demonstration that mask ventilation is possible is performed before the administration of neuromuscular blockers and an attempt at intubation. In obstetric anesthesia, a rapid sequence induction is usually performed due to the aspiration risk; thus, it is unknown whether mask ventilation is successful before intubation attempts. When intubation is difficult, as demonstrated by the laryngeal view, or when there is failure to intubate, mask ventilation must be attempted to ensure oxygenation and ventilation. Because of the increased weight in

pregnancy, and the edema, mask ventilation can be difficult.

Oral airways are introduced to improve the efficiency of mask ventilation. Nasal airways can also be utilized. However, the increased vascularity of the nasal mucosa increases the potential for bleeding, which would make the already difficult airway more difficult. Manipulation of the airway with the aim of improving the seal of the mask is important. Many algorithms and authors suggest that two people may be necessary, one to maintain a seal of the mask and airway while the other (less experienced provider) ventilates the patient [26]. It is advocated that cricoid pressure be maintained while this is occurring. If mask ventilation is inadequate with cricoid pressure, the cricoid pressure should be relieved to see if ventilation improves. Tunstall [56] advocated that, prior to removing cricoid pressure, the patient should be placed head-down, because if vomiting or regurgitation occurs in this position, vomitus is less likely to enter the trachea and lungs. The aim of Tunstall's failed intubation drill was, he stated, "oxygenation without aspiration".

The first step in the difficult or failed obstetric airway is to maintain oxygenation and ventilation through bag mask ventilation. Once this first essential step has been performed, further assessment of the maternal and fetal status is undertaken. The obstetric team present needs to give input at this stage and guide the anesthesiologist regarding the necessity for immediate or nonurgent delivery of the baby.

Unexpected difficult intubation, can ventilate

Nonurgent delivery

In the case of nonurgent delivery, unexpected difficult intubation *cannot intubate, can ventilate*, the suggested course of action is to awaken the mother and then to use either a regional anesthesia or an awake intubation technique. Case series have demonstrated that this approach works [38].

Urgent delivery

In the case of urgent delivery, unexpected difficult intubation *cannot intubate, can ventilate*, a suggested course of action is to continue to mask ventilate with cricoid pressure, induce anesthesia with a volatile anesthetic, allow for resumption of spontaneous ventilation if possible, and continue with delivery. Left lateral tilt and Trendelenburg position should be maintained. Cricoid pressure can be released if it impedes ventilation. Again, case series suggest that this approach is practical [38].

Other devices used successfully include the LMA, intubating LMA, and ventilating LMA [57,58]. Details of these procedures have been published as case reports, with the potential for associated selection and publication biases.

Han et al. [59] described a series of 1067 patients undergoing elective cesarean section in whom the LMA was used and concluded that "the LMA is effective and probably safe for elective cesarean section." However, this study included only low-risk, fasted, elective cesarean section cases, and the definition of "safe" is still questionable.

Unexpected difficult intubation: cannot intubate cannot ventilate

Nonurgent delivery

In the case of *cannot intubate, cannot ventilate*, the aim is to awaken the patient and use a regional anesthesia or awake intubation technique. However, it is essential to maintain oxygenation of the patient. Apneic oxygenation may maintain adequate oxygen saturation during this period. Although adequate ventilation may be impossible, partial incomplete bag mask ventilation may suffice in the interim, allowing oxygenation and ventilation while the patient wakens. Evidence to provide documentation and support for this step is scarce (even when one considers case reports). The use of nonsurgical techniques to maintain oxygenation and ventilation while waiting for the patient to awaken is described in the next paragraph.

Urgent delivery

In this situation, when intubation is difficult and ventilation is difficult or impossible, the decision must be made to proceed to a nonsurgical or surgical airway (or combination thereof), or if all fails, then performance of a cesarean delivery with infiltration of local anesthetic. The technique chosen usually depends on the experience or "comfort level" of the anesthesia care provider with specific techniques. It is important to note that the anatomical and physiological changes occurring during pregnancy may make oxygenation and ventilation difficult with an LMA, Combitube (Kendall-Sheridan Catheter, Argyle, MA, USA), or needle jet ventilator technique. High airway pressures need to be generated by these devices, because of decreased lung compliance associated with pregnancy and any lung injury. The high pressure may lead to barotrauma and inadequate oxygenation and ventilation. It is important to determine oxygenation and ventilation at each intervention at this stage in cesarean delivery.

Use of the LMA or Combitube has been suggested in this subgroup. Case reports have described the successful use of the LMA and ILMA in the failed obstetric intubation with *cannot intubate, cannot ventilate* situa-

tion [60–64]. In a survey of obstetric anesthesia consultants in the United Kingdom, 72% of the respondents stated that they would use the LMA in the *cannot intubate, cannot ventilate* obstetric airway, and the survey suggested that the LMA was available in 91% of obstetric units [65]. Twenty four (of 250) consultant anesthetists had personal experience with the use of the LMA in obstetric anesthesia. Although complete details of the use were not provided, 8 stated that it was lifesaving, 2 stated that attempts to pass a gum elastic bougie through the LMA failed, and 3 had used the LMA but without success. Twenty-two consultant anesthetists were against the use of the LMA, the risk of aspiration being the principal reason given. The ventilating LMA has the potential to offer the advantage of allowing ventilation while decreasing the risk of aspiration. However, the device has been approved by the Food and Drug Administration for ventilation up to 30 cm H_2O only. The ILMA has potential advantages, as it will allow the introduction of a definitive airway. There are no case reports in the literature describing the use of the Combitube in the difficult obstetric airway [66]. It has been used with success in anesthetic cases in the operating room. Aspiration is the main potential complication with this device. There is a case report suggesting an esophageal perforation; however, multiple airway devices were used [67].

Surgical techniques suggested for the urgent delivery *cannot intubate, cannot ventilate* situation include transtracheal jet ventilation, cricothyrotomy, and tracheotomy. There are no case reports documenting the use of transtracheal jet ventilation in the difficult or failed obstetric airway. High airway pressure may be required to overcome the decreased lung compliance seen in pregnancy. Acute lung injury secondary to pulmonary aspiration will decrease lung compliance even further, making it difficult to maintain oxygenation and ventilation with jet ventilation. Also, without a secured airway, pulmonary aspiration may result. There is a paucity of case reports of the use of cricothyrotomy (either surgical or using the Seldinger technique) in the difficult or failed obstetric airway. These techniques are used infrequently by anesthesiologists, though emergency room physicians and surgeons tend to use these techniques if the airway has proven difficult. When either the Seldinger technique or surgical cricothyrotomy was performed on cadavers by inexperienced medical personnel, the techniques were equally poorly performed. In the obstetric setting it is difficult to find a case report detailing an emergency tracheotomy in the difficult or failed airway. Obstetricians usually do not have as much familiarity with the technique of tracheotomy compared with general surgeons. This may, in part, explain why tracheotomy has not been used in labor and delivery. The advice is to use the technique with which the anesthesiologist is most comfortable. Becoming familiar and practicing with difficult airway equipment is crucial.

Difficult airway equipment in obstetrics

When one encounters a difficult or failed obstetric airway, it is essential to have difficult airway equipment available. There are different approaches. One approach is to have every anesthesia machine equipped with one or two pieces of emergency airway equipment. This may consist of the LMA and/or gum elastic bougie. These two pieces of equipment, or their equivalents, will be of benefit in most airway emergencies. Although each piece of equipment is inexpensive, fitting out each anesthesia location will add to the expense. Many anesthetic departments have developed the opposite approach, by creating "difficult airway carts." The aim is to have all difficult airway equipment available in one portable cart. Continued upkeep is needed to ensure the equipment is in working order when required. Table 3 lists the specialized intubation equipment of one such airway cart used at Mayo Clinic.

Conclusion

The difficult and failed obstetric airway is a problem for all involved in the care of the pregnant patient in the labor and delivery room. All anesthesia providers must be trained in the assessment and care of the obstetric airway, both the straightforward and the difficult airway. Individuals from other disciplines who work in the obstetric suite need to have an appreciation of the difficulty involved in securing a parturient's airway and to recognize when the anesthesia provider needs additional help or equipment.

Anesthesia care providers must provide leadership in airway management issues at both local and national levels. Locally, they must be responsible for the education and training of obstetric staff relating to airway management and other aspects of anesthesia practice.

Table 3. Major equipment used in the difficult airway cart at Mayo Clinic

1	Flexible fiberoptic bronchoscope
2	Bullard laryngoscope, Circon, Stanford, CT, USA
3	ProSeal laryngeal mask airway, LMA North America, San Diego, CA, USA
4	Intubating laryngeal mask airway
5	Combitube, Kendall-Sheridan Catheter, Argyle, MA, USA
6	Trachlight, Laedal Medical, New York, NY, USA
7	Jet ventilation apparatus
8	Cricothyrotomy seldinger kit

They must measure outcomes through continuous quality assurance. Although poor outcomes, death, and cerebral hypoxia have decreased substantially it is important to monitor the number of maternal intubations and other endpoints, such as acute lung injury and failure to intubate. A difficult and failed airway algorithm needs to be in place for each labor and delivery room. Although there has been an increase in the number of specialized obstetric anesthesiologists, it is necessary to ensure that all anesthesia care practitioners are aware of the protocol and are skilled in the performance of each of the steps. At the national level, general and specialized societies interested in the care of the obstetric patient must cooperate and act together to optimize airway management in obstetrics, especially for the difficult and failed airway. Although, in developing countries, the maternal mortality rate is regarded as a direct indicator of the healthcare of a nation, in developed countries in the twenty-first century, maternal mortality may reflect the health of the specialty of anesthesia.

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