# 21 Airway Management during Pregnancy and the Peripartum Period

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**Bullet Points**

- Factors contributing to the challenges of the pregnant airway are airway edema, respiratory and metabolic changes, weight gain and obesity, breast enlargement, gastroesophageal changes, and increased aspiration risk.
- Readiness is crucial for every unit caring for obstetric patients, and a difficult airway cart with adequate and sufficient equipment is essential.
- Preoxygenation prolongs the safe apnea time and can be assessed by measuring the end-tidal oxygen concentration (achieved when above 90%), which denotes successful denitrogenation.
- Waveform capnography confirms that the endotracheal tube is in the trachea and remains the gold standard of confirmation; it should be routinely used in intubated patients in critical care units.
- Advanced techniques include waveform capnography, direct laryngoscopy, or videolaryngoscopy confirming endotracheal tube in the vocal cords, or flexible scope visualization of the tracheal lumen.
- Awake intubation carries the advantage of maintaining airway patency and spontaneous ventilation; it may be performed via a flexible optical scope, videolaryngoscopy, intubation with second-generation supraglottic airways, tracheostomy, cricothyroidotomy, and by retrograde intubation.

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## 21.1 Incidence of Difficult Airway and Failed Intubation in Obstetrics

Failed tracheal intubation in the pregnant patient is a dramatic situation as the presence of fetus(es) means that more than one life could potentially be compromised if severe hypoxia occurred during difficult airway management.

The incidence of failed intubation in the obstetric population is eight times higher than that in the general population. It has remained unchanged over the past four decades at 1:390 for general anesthesia (GA) in the obstetric population and 1:443 for cesarean deliveries [1]. In busy


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tertiary obstetric centers with higher GA rates for cesarean deliveries with 24/7 specialist coverage, the failed intubation incidence may actually be lower (1:462) [2].

The Fourth National Audit Project (NAP4) of the Royal College of Anaesthetists and Difficult Airway Society (DAS) report from 2011 identified the maternal mortality rate from failed intubations to be approximately 2.3 per 100,000 GAs for cesarean delivery (1 death per 90–102 failed intubations) compared to 1:180,000 GAs for the general population [3]. Key learning points gleaned from this report were that physiological changes in pregnancy, active labor, and the often remote and isolated location of labor and cesarean delivery rooms increase the complexity of management of airway complications when they occur, and the presence of fetus(es) further complicates management.

Compared to the early 1980s when a high number of cases of difficult, failed intubation and/or failed ventilation used to regularly feature in the Reports on Confidential Enquiries into Maternal Deaths, fueling clinician's worries about managing the obstetric airway, it is encouraging that such incidences have reduced considerably over the years due to the greater use of neuraxial anesthesia in obstetrics and in part due to better training, staffing, equipment, and facilities. However, the potential for a failed intubation remains. There is also concern that changes in anesthetic training in the United Kingdom and the United States, as well as reduced number of GAs for cesarean deliveries, have led to reduced exposure of trainees to practice the skills necessary for obstetric airway management [4, 5].

In the 2006–2008 Center for Maternal and Child Enquiries (CMACE) report, two of the seven anesthesia-related deaths resulted from failure to ventilate, leading to a recommendation that because effective management of failed tracheal intubation is a core anesthetic skill, it should be taught and rehearsed regularly, with the use of simulation for teaching and rehearsing failed intubation strongly recommended [6]. Indeed, recent data has corroborated this, with data collected between 2008 and 2010 using the UK Obstetric Surveillance System reporting an incidence of failed intubation of 1:224 [7] and data collected between 2006 and 2013 in a US academic center reporting a 1:232 incidence [8], with only 3 failed intubations out of 695 GAs, all successfully managed with a laryngeal mask airway with no adverse maternal or fetal outcomes directly related to failed intubation. Advances in adjunct airway equipment, availability of an experienced anesthesiologist, and simulation-based teaching of failed airway management in obstetrics were contributory factors to the improved maternal outcomes in these patients. It is timely that the recent publication of the Obstetric Anaesthetists' Association (OAA) and DAS guidelines for the management of difficult and failed tracheal intubation in obstetrics includes an algorithm for "Safe obstetric general anesthetic" which is designed to be used as a teaching tool to update and standardize the conduct of GA for pregnant women [9].

## 21.2 Maternal Airway Challenges

Airway management in pregnancy is more challenging than in the nonpregnant state due to several factors:

### 21.2.1 Maternal Anatomic and Physiologic Factors

#### 21.2.1.1 Airway Edema

Increased maternal blood volume and higher estrogen levels result in mucosal edema, capillary engorgement, and increased tissue friability. Hence intubation, insertion of nasal airways, orogastric, or nasogastric tubes, is associated with increased bleeding tendency. Epistaxis and soft palate hematoma can occur even after little or minimal unprovoked trauma [10]. Edema distorts laryngeal anatomy, narrowing apertures and mandates intubation with smaller sized diameter tracheal tubes. In addition, specific pregnancy-associated comorbidities such as preeclampsia, more frequent respiratory tract infections, and oxytocin augmentation of labor with resultant water retention, over-zealous fluid administration, combined effects of prolonged Valsalva efforts, and maternal pushing during the second stage of labor can significantly worsen the airway edema. Pre-labor Mallampati classifications worsen during labor and evaluations should be repeated prior to intubation; [11, 12] these changes extend to 48 h after delivery [13]. A high Mallampati score (class 3 or 4) was thought to strongly associate with difficult intubation, with historical data reporting increased relative risks of 7.6 and 11.3, respectively [14], but recent studies were not able to correlate findings from preoperative bedside tests and actual intubation difficulty in women who underwent cesarean delivery under GA (see Chap. 20).

#### 21.2.1.2 Respiratory, Metabolic Changes, and Denitrogenation

The enlarging gravid uterus pushes the diaphragm cephalad causing 15–30% reduced expiratory reserve volumes and decreased functional residual capacity (FRC). Early airway closure can occur at normal tidal volume breathing exacerbated in supine, Trendelenburg, and pregnant women with high body mass index (BMI). Increased oxygen consumption, the pain and stress of labor, potentiates rapid hypoxemia necessitating denitrogenation (administration of a maximal fraction of inspired oxygen ($Fi0_2$) with tight fitting mask) prior to rapid sequence induction (RSI) to achieve the longest apneic duration before desaturation. This is best achieved by elevating the head of the bed 25 degrees [15]. The standard technique for preoxygenation is to breathe 100% oxygen for 3–5 mins of tidal volume; [16] however given the emergent nature of GA in obstetrics, eight deep breaths over 60 s have been shown to provide adequate denitrogenation as measured by end-tidal fractional oxygen concentration ($F_{\mathrm{ETO2}}$) [17].

#### 21.2.1.3 Obesity and Weight Gain

By 2025, the global obesity prevalence will surpass 21% in women [18]. The Centers for Disease Control and Prevention (CDC) reported that 34.9% of adults in the United States had a BMI above 30 in 2011–2012 [19], with this figure projected to be 50% by 2025 [20]. The average weight gain during pregnancy in women with a BMI between 25 and 29.9 is 15.3 ± 6.8 kg [21], due to increased fat deposition, blood and interstitial fluid volume, uterus, and the enlarging fetus. Obese patients have a threefold increased risk of difficult intubation [22], and high BMI is a risk factor on univariate analysis for both difficult/impossible mask ventilation and difficult endotracheal intubation [23]. Obesity results in greater reduction in FRC, higher metabolic demands, increased oxygen consumption, and more rapid desaturation during apnea. Using a computational simulator, preoxygenation with 100% oxygen was followed by simulated RSI, a laboring parturient with a BMI of 50 demonstrated the fastest desaturation, defined as the time taken for arterial oxygen saturation ($SaO_2$) to decline below 90% (98 versus 292 s in a non-obese pregnant case) [24]. Morbidly obese pregnant patients are also at increased risk of postpartum hemorrhage, cephalopelvic disproportion resulting in higher rates of emergency cesarean deliveries and instrumental deliveries. Delayed childbearing and increased use of assisted reproduction techniques result in an older and more obese obstetric population [25], with higher risk of emergency cesarean deliveries, failed epidural anesthesia, pulmonary aspiration of gastric contents, and maternal death from airway complications [26, 27]. Comorbid pre-eclampsia, hypertension, and gestational diabetes in older pregnant women can potentiate and exacerbate the effects of hypoxemia, hypercarbia, and acidosis during a delayed or failed intubation.

Severely obese parturients have an increased “can’t intubate, can’t oxygenate” (CICO) risk. The cricothyroid membrane (CTM) is the last portal of escape for emergency oxygenation and definitive management for front-of-neck access (FONA) and cricothyrotomy when a failed intubation scenario arises. However, attempted FONA can fail because computerized tomography (CT) studies have shown that the CTM is not necessarily a superficial structure in women of childbearing age [28]. The cricothyroid membrane is indeed a deep structure, especially in the morbidly obese (BMI > 45) where it may be difficult to palpate and identify [29]. Clinicians poorly identify the cricothyroid membrane by digital palpation, succeeding in only 39% (11/28) of obese compared to 71% (20/28) of non-obese pregnant patients [30]. Hence, point-of-care ultrasonography (POCUS) of the upper airway [31] is currently the best modality to provide useful information about the cricothyroid membrane's location and depth to aid FONA in obesity [32–34], with ultrasound being a natural choice and superior to CT scans as it avoids ionizing radiation to both mother and fetus(es) (see Chap. 35).

#### 21.2.1.4 Breast Enlargement

Mammomegaly in supine pregnant women often impedes the insertion and manipulation of the laryngoscope to achieve good glottic visualization. The "head-ramped" position (where the external auditory meatus is aligned horizontally with the sternal notch) is advocated [35]. This semi-upright position achieved by placing blankets, pads, or other commercially available positioning devices under the shoulders, neck, and occiput significantly improves the laryngeal view and is superior to the "sniffing position" when intubating obese pregnant women (Fig. 21.1) [36]. Using a short-handled laryngoscope [37], getting an assistant to push the breasts caudally and detaching the laryngoscope handle from the blade then inserting the blade first into the mouth before reattachment are other strategies to minimize the difficulty in positioning the laryngoscope.

**Fig. 21.1** Troop pillow illustrated here in an obstetric operating room, allowing safe ramping up in case of urgent or emergent general anesthesia with endotracheal intubation (here shown with back of the table in 'ramped down') position

#### 21.2.1.5 Gastroesophageal Changes and Aspiration Risk

Although maternal mortality from pulmonary aspiration of gastric contents has declined to negligible rates in the last three decades [6, 38–41], due to increased neuraxial analgesic/anesthetic techniques for cesarean delivery, pregnant women remain at risk for regurgitation and aspiration of gastric contents due to hormonal changes (increased gastrin, decreased motilin, and progesterone-induced relaxation of gastrointestinal smooth muscle decreasing lower esophageal sphincter tone). The relative risk of aspiration in pregnant versus nonpregnant women is best estimated from comparisons within single-study populations. Historical data identified a threefold higher aspiration risk in women undergoing cesarean delivery, with an overall incidence of aspiration of 1:2131 in the general population undergoing anesthesia versus 1:661 in parturients [42].

Labor and neuraxial opioids were historically believed to delay gastric emptying [43], although recent work on ultrasonographic quantification of gastric antrum volumes in laboring women suggests that gastric motility is preserved under epidural anesthesia [44, 45]. In third trimester gestation, an antral cross-sectional area of 9.6 $cm^2$ in the semi-recumbent right lateral position discriminated for high gastric volumes $\geq 1.5$ mL $kg^{-1}$, demonstrating potentially increased aspiration risk [46, 47]. The recent 2016 "Practice Guidelines for Obstetric Anesthesia: An Updated Report by the American Society of Anesthesiologists Task Force on Obstetric Anesthesia and the Society for Obstetric Anesthesia and Perinatology" recommend timely administration of nonparticulate antacids, H2-receptor antagonists, and/or metoclopramide for aspiration prophylaxis before surgical procedures such as cesarean delivery or postpartum tubal ligation [48].

### 21.2.2 Environmental/Situational and Anesthetic Factors

Situational urgency and time pressure to deliver the baby have typically resulted in suboptimal decision-making and fixation error by clinicians during critical situations. Similarly, in situations when a critically ill pregnant woman needs to be intubated, the emergency of the situation, in the presence of fetus(es) (that may or may not yet be delivered), requires adequate education of all involved in the procedure itself and readiness of the environment and staff. Training issues prevail due to reduced clinical experience of anesthetic trainees and assistants related to the low exposure to GA for cesarean deliveries and dwindling use of GA, as well as the rarity of circumstances of a critically ill pregnant woman requiring an intubation in the ICU. These are key educational elements for the success of an emergent intubation under these unique circumstances.

## 21.3 Safe General Anesthesia for Healthy Pregnant Patients

The OAA/DAS Obstetric Difficult Airway Guidelines proposed an updated conduct for safe obstetric GA (Algorithm 1; Fig. 21.2) [9]. Planning and preparation are emphasized with airway assessment, fasting whenever possible,

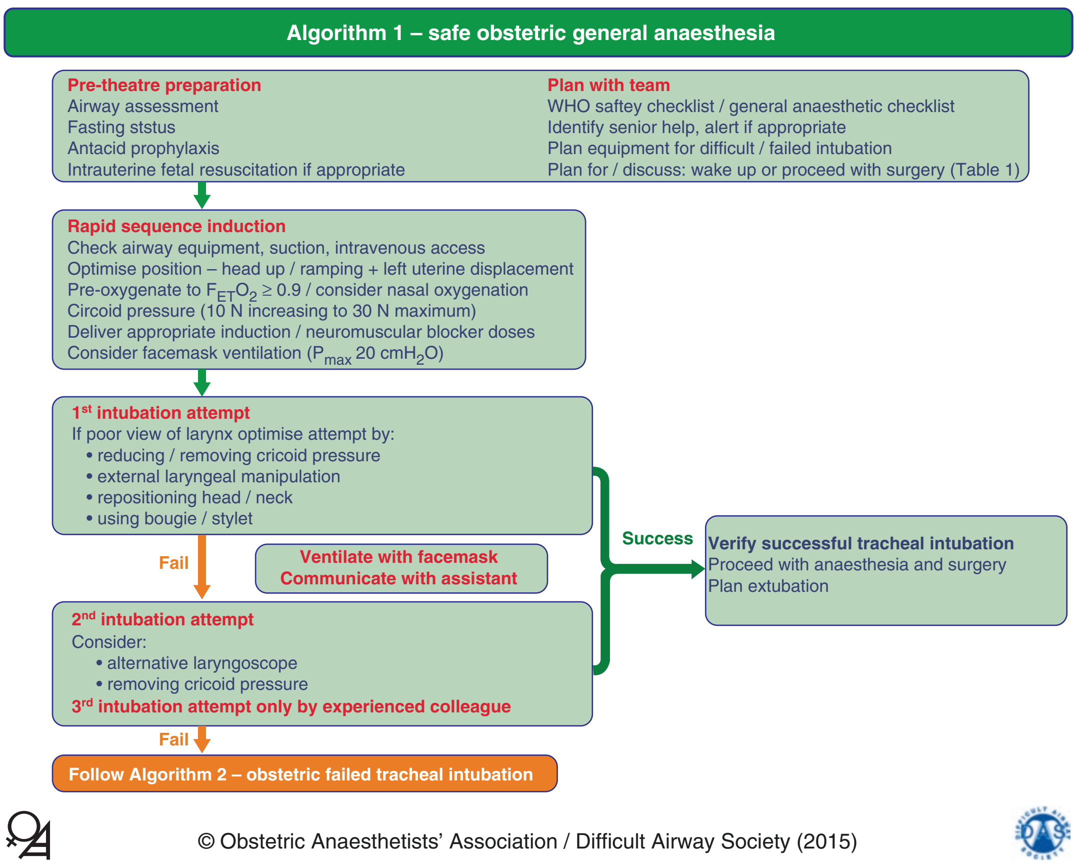


**Fig. 21.2** Algorithm 1—safe obstetric general anaesthesia of the OAA/DAS Obstetric Difficult Airway Guidelines (Reproduced with permission)

antacid prophylaxis, and intra-uterine fetal resuscitation where appropriate. If the GA is provided with the intent of delivering the fetus (cesarean delivery), there should be concurrent team discussion whether to wake the mother or proceed with anesthesia without endotracheal tube in the event of failed intubation. This decision is influenced by several presenting factors related to the woman, fetus, anesthesiologists' experience, and clinical situation, as outlined in the OAA/DAS Obstetric Difficult Airway Guidelines (Table 21.1; Fig. 21.3).

The fifth National Audit Project of the RCoA (NAP5) [49] found a higher incidence of awareness in obstetric GAs and in patients with unanticipated difficult airway. It is therefore recommended that additional induction agent should always be available and be administered should a difficult airway be encountered. There is no consensus whether short-acting opiates should be used routinely in obstetrics instead of only reserving their use in specific situations such as preeclampsia or in patients with cardiac disease.

**Table 21.1** Suggested equipment and drugs for a difficult airway cart

| | |
|---|---|
| Basic airway equipment | Face masks<br>Oral airways<br>2 working laryngoscope handles<br>Macintosh blades size 3 and 4<br>6.5–7.0 mm endotracheal tubes with stylet<br>Empty 10 ml syringe to inflate the pilot balloon<br>Backup endotracheal tubes in a range of sizes<br>Gum elastic bougie<br>Second-generation supraglottic airways (SGA)<br>A working suction apparatus |
| Secondary intubation equipment | Other direct laryngoscopes (McCoy blade, Miller blade)<br>Videolaryngoscopes<br>Optical stylets or intubation conduits<br>Fiberoptic bronchoscope<br>Surgical airway kit |
| Drugs for intubation | Propofol, midazolam, etomidate, ketamine<br>Succinylcholine<br>Rocuronium, sugammadex |

### 21.3.1 Algorithms for Management of Difficult Intubation

The OAA/DAS obstetric guidelines propose an obstetric failed tracheal intubation algorithm (Algorithm 2; Fig. 21.4) [9]. When first attempt at endotracheal intubation fails, face mask ventilation should be performed while communicating with the team. The second intubation attempt should be done by the most experienced anesthesiologist present using a different laryngoscope and with the cricoid pressure removed. Only two attempts are recommended, and a third attempt should only rarely be done (and this must be done by the most skilled, different anesthesiologist) as airway swelling can develop very rapidly, converting a "can oxygenate, can't intubate situation" to a CICO. Three failed optimal laryngoscopy attempts should invoke the failed intubation drill with early call for help. Here, oxygenation and ventilation should take priority over intubation, using either a face mask or second-generation supraglottic airway (SGA). If face mask was found to be difficult prior to the intubation attempt and if the preinduction team decision was to proceed with surgery, then immediate insertion of the SGA is the preferred airway rescue strategy. If oxygenation or ventilation is impossible at any point of the algorithm, then a CICO scenario (Algorithm 3; Fig. 21.5) is declared, and surgical rescue airway is indicated [9]. Failed oxygenation resulting in maternal cardiac arrest mandates a perimortem cesarean delivery within 4–5 min of the arrest to optimize the effectiveness of chest compressions for maternal resuscitation [50].

## 21.4 Airway Management of the Critically ill Pregnant Patient

### 21.4.1 Hazards of ICU Airway Management

ICU patients' airways are extremely demanding with significantly greater incidence of airway-related mortality and severe morbidity than that

**Table 1 – proceed with surgery?**

| | Factors to consider | WAKE | ⟵ | ⟶ | PROCEED |
|---|---|---|---|---|---|
| Before induction | Maternal condition | • No compromise | • Mild acute compromise | • Haemorrhage responsive to resuscitation | • Hypovolaemia requiring corrective surgery<br>• Critical cardiac or respiratory compromise, cardiac arrest |
| Before induction | Fetal condition | • No compromise | • Compromise corrected with intrauterine resuscitation, pH < 7.2 but > 7.15 | • Continuing fetal heart rate abnormality despite intrauterine resuscitation, pH < 7.15 | • Sustained bradycardia<br>• Fetal haemorrhage<br>• Suspected uterine rupture |
| Before induction | Anaesthetist | • Novice | • Junior trainee | • Senior trainee | • Consultant / specialist |
| Before induction | Obesity | • Supermorbid | • Morbid | • Obese | • Normal |
| Before induction | Surgical factors | • Complex surgery or major haemorrhage anticipated | • Multiple uterine scars<br>• Some surgical difficulties expected | • Single uterine scar | • No risk factors |
| Before induction | Aspiration risk | • Recent food | • No recent food<br>• In labour<br>• Opioids given<br>• Antacids not given | • No recent food<br>• In labour<br>• Opioids not given<br>• Antacids given | • Fasted<br>• Not in labour<br>• Antacids given |
| Before induction | Alternative anaesthesia<br>• regional<br>• securing airway awake | • No anticipated difficulty | • Predicted difficulty | • Relatively contraindicated | • Absolutely contraindicated or has faild<br>• Sugery started |
| After failed intubation | Airway device / ventilation | • Difficult facemask ventilation<br>• Front-of-neck | • Adequate facemask ventilation | • First generation supraglottic airway device | • Second generation supraglottic airway device |
| After failed intubation | Airway hazards | • Laryngeal oedema<br>• Stridor | • Bleeding<br>• Trauma | • Secretions | • None evident |

Criteria to be used in the decision to wake or proceed following failed intubation. In any individul paitient, some factors may suggest waking and others proceeding. The final decision will depend on the anaethetist's clinical judgement.



**Fig. 21.3** Factors involved in the decision-making about whether to proceed or wake up a patient following failed intubation (Reproduced with permission)

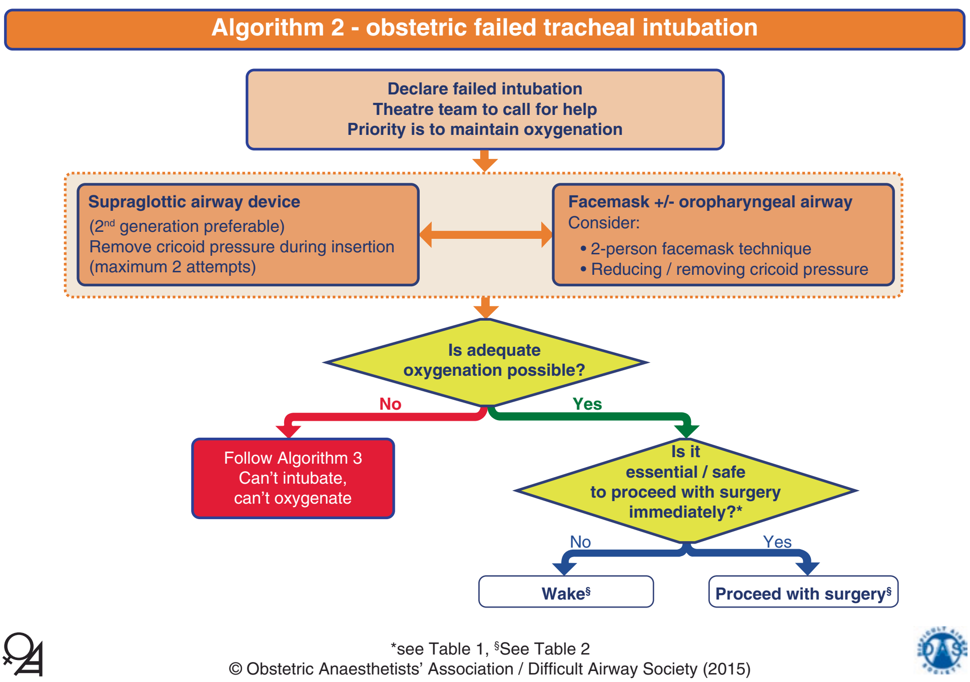


**Fig. 21.4** Algorithm 2—failed intubation algorithm

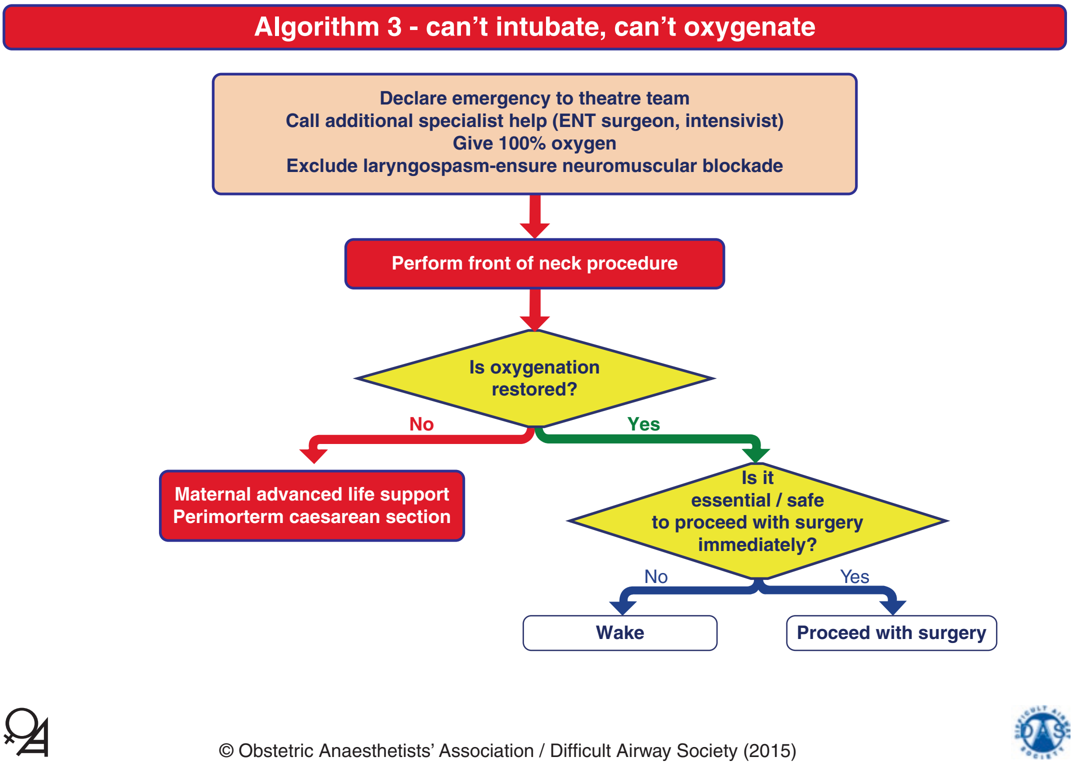


**Fig. 21.5** Algorithm 3- can't intubate, can't oxygenate (CICO) scenario

encountered in general operating room (OR) practice [3]. Studies quantifying airway difficulties per se in the ICU are scarce, but a report on 3423 nonoperating room emergent endotracheal intubations performed by anesthesia residents was reviewed, with 60% occurring in the ICU [51]. The NAP4 of the Royal College of Anaesthetists was a nationwide, prospective observational 1-year audit in the United Kingdom that collated data from the OR, emergency department (ED), and ICU. They studied airway-related mortality, brain damage, emergent surgical access, ICU admission, or prolongation of ICU stay [3]. NAP4 found 38 airway-related deaths: 16 in the OR, 4 in the ED, and 18 in the ICU. With a denominator of 2.9 million anesthetics performed in the OR, 20,000 endotracheal intubations in the ED, and 58,000 episodes of advanced respiratory support in ICU, airway-related death was found to be 58 times more common per patient in the ICU than in the OR [3]. Death or brain damage rates were 61% when difficult airways were encountered in the ICU compared to 14% in the OR. This translates to airway-related mortality rates of 1 in 2700 ICU patients versus 1 in 180,000 in the OR [52].

ICU patients are physiologically compromised, having significant ventilation–perfusion (VQ) scan abnormalities and lower functional residual capacities: preoxygenation is less effective and apnea tolerated poorly. Patients are frequently unfasted or have delayed gastric emptying. The intubation is often urgent, with little time for assessment or preparation. Airway assessment in the critically ill is problematic, so difficulty is often unanticipated. Ideal airway intervention must therefore be prompt and smooth, as the critically ill simply do not tolerate poor airway management, what more a pregnant patient with two lives at stake when faced with the need to intubate a deteriorating eclamptic, or parturient with significant respiratory disease [53], pneumonia, hypoxemic respiratory failure, hemodynamic instability, impaired consciousness, angioedema, Ludwig's angina, acute epiglottitis, sepsis, or multi organ failure.

Thorough preoxygenation, the competent use of videolaryngoscopes, and an intubation checklist incorporating RSI are key management strategies. However, the hazards of airway management in the ICU only begin once the tube is inserted. An intubated patient care bundle including capnography needs to be instituted to exclude esophageal intubation, with continued vigilance for partially displaced tubes and displaced airways especially in the obese, agitated, and during patient transfers to imaging facilities. Successful airway management requires training and a well-formulated airway plan that is shared with the entire team and that uses equipment with which team members are proficient. Difficult extubation, endotracheal tube exchange techniques, tracheostomy insertion, and care are unique to ICU airway management (beyond the scope of this chapter), and proficiency in dealing with tracheostomy emergencies, bleeding, obstruction, partially displaced tubes is a core ICU skill.

### 21.4.2 Equipment and Readiness

A well-stocked portable difficult airway cart is essential for every unit caring for obstetric patients. Airway carts throughout the hospital should be standardized including in the OR, ED, and ICU. Equipment should be purchased with the least experienced potential user in mind. Suggested equipment are listed (Table 21.1) [54, 55].

#### 21.4.2.1 Drugs

ICU patients are often hypovolemic, septic, and/or in hemodynamic shock. A third of all severe complications of ICU endotracheal intubation are hemodynamic [56], and this affects the choice of pharmacological agent to facilitate intubation. Etomidate or ketamine is the most commonly used induction agents in shocked patients, but etomidate's use has been questioned because of its suppression of 11β-hydroxylase, which causes relative adrenal insufficiency and purportedly increases mortality, with some authorities asking to abandon its use [57, 58]. Ketamine is an excellent induction agent for ICU patients; it provides dissociative sedation and preserves spontaneous respiration with intact airway reflexes. The primary concern regarding ketamine is its elevation of intracranial pressure, but its positive effect on arterial blood pressure also results in increased cerebral perfusion pressure, so its use is increasingly prevalent in trauma and head-injured patients so long the patient is adequately ventilated [59–61]. Propofol remains a popular induction agent to facilitate endotracheal intubation by anesthesiologists, but its use in the ICU patient can exacerbate hypotension. Nonetheless, experience in using a particular drug can have excellent outcomes, as demonstrated by critical care doctors in Scotland (national study of 794 intubations over 4 months, 70% occurring in ICU and 18% ED) [62]. Their first-time intubation success rate was 91%; no patient required more than three attempts at intubation, with three-quarters of intubations performed by doctors who had undergone >24 months formal anesthetic training, with routine supervision of junior trainees. Generally, the dose of sedative agents can be decreased 30% to 50% in ICU patients. Using neuromuscular blocking agents (NMBAs) allows further reductions in induction dose [63]. Succinylcholine is the traditional NMBA used in the ICU. A recent 2015 Cochrane review found intubating conditions of rocuronium 1.2 mg/kg and succinylcholine 1 mg/kg to be equivocal; however succinylcholine was clinically superior due to its shorter duration of action [64]. When intubating hemodynamically unstable ICU patients, one must bear in mind that the speed of onset of rocuronium is dependent on cardiac output [65]. Anaphylaxis occurrence with succinylcholine and rocuronium is similar [66]. Sugammadex (16 mg/kg) must be immediately available to effectively reverse an RSI dose in less than 10 min [67]. Succinylcholine fasciculation raises oxygen consumption and precipitates earlier desaturation of 116 s compared to rocuronium [68]. Succinylcholine-induced hyperkalemia from development of extrajunctional acetylcholine receptors with prolonged immobility is a dangerous concern. There is no clear guidance as to the duration of immobilization that puts patients at highest risk, with many clinicians using 10–14 days as a cutoff [69, 70].

### 21.4.3 Airway Assessment

Assessing the maternal airway for features of a difficult airway allows anticipation of equipment needs and backup B and C plans should plan A fail. If the plan is for an imminent cesarean delivery, and the GA is not needed for other indications (respiratory support), prevention of airway problems is best achieved by early placement of an epidural catheter (particularly in the morbidly obese or preeclamptic parturient) [48]. Cormack and Lehane's four laryngeal grades of structures visualized on direct laryngoscopy [71] are significantly correlated with the Mallampati class [72]. A higher Mallampati score (of III and IV), presence of a short neck, protruding incisors, or a receding mandible, is known to increase the relative risk of intubation difficulty in pregnancy [14]. Other multivariate tools to assess airway difficulty are the Wilson Risk Sum index [73] and the el-Ganzouri index [74]. The latter's seven criteria of mouth opening, thyromental distance, neck movement, mandibular protrusion, body weight, Mallampati class, and history of difficult intubation are independent predictors of difficult intubation (see Chap. 20). However, emergent ICU intubation precludes detailed assessment and is often fraught with problems (hypoxic uncooperative patient, eclamptic, secretions, blood, vomit in airway, cervical spine collars in place precluding cervical spine mobility assessment).

De Jong developed the MACOCHA score which is the only ICU-specific assessment tool to evaluate risk factors for difficult intubation [75]. It comprises seven items (factors related to patients: Mallampati 3 or 4, obstructive sleep apnea syndrome, reduced cervical spine mobility, limited mouth opening <3 cm; or factors related to pathology: coma, severe hypoxemia <80%; or factor related to operator: non-anesthesiologist) coded from 0 to 12, where 0 = easy and 12 = very difficult. A score of 3 or greater is the cutoff value denoting difficult intubation with a high discriminant value [76]. The MACOCHA predictive score is unique as it scores operator experience: specifically, anesthesia training of at least 24 months, and includes two ICU-specific criteria: hypoxemia and coma before intervention, important because hypoxia permits less time for preparation, leads to quicker desaturation, and may increase operator stress; coma makes assessment more difficult and is associated with greater laryngeal contamination. If there is a history suggestive of upper airway obstruction, flexible nasal endoscopy is a valuable tool [77]. Predictors of difficult mask ventilation and supraglottic airway ventilation have been described but not validated in the ICU setting [78–81].

### 21.4.4 Rapid Sequence Induction and Intubation (RSI)

*Technique*: The definition of RSI varies but certainly includes preoxygenation and an induction dose of IV hypnotic followed by a rapid-onset neuromuscular blocking agent. ICU patients are rarely fasted and have functional ileus and at high risk of regurgitation and pulmonary aspiration when given sedatives to allow endotracheal intubation. All critical care physicians should learn to perform RSI and adopt it as the standard mode of intubation for critically ill patients [81, 82]. The RSI technique is part of the only intubation bundle seen to reduce complications of ICU endotracheal intubation, the ICU intubation bundle management protocol, in which ten components have been delineated and proposed [82].

Before intubation:

1. Presence of two operators.
2. Fluid loading (in the absence of cardiogenic pulmonary edema).
3. Preparation of long-term sedation.
4. Preoxygenation with noninvasive positive-pressure ventilation.

During intubation:

1. Rapid sequence induction.
2. Cricoid pressure.

After intubation:

1. Immediate confirmation of tube placement by capnography.
2. Vasopressor use if needed.
3. Early administration of sedation.
4. Initial "protective ventilation" (tidal volume 6–8 mL/kg of ideal body weight, PEEP <5 cm $H_2O$, respiratory rate between 10 and 20 cycles/min).

Adapted from this initial work [82], an ICU RSI intubation care bundle was developed which incorporates checklists and lists personnel responsible for which task and is an approach amenable to ongoing teamwork and simulation training (Table 21.2) [83].

*Cricoid Pressure*: In the classic RSI, cricoid pressure is applied, and no face mask ventilation occurs between induction and endotracheal intubation; however, gentle face mask ventilation during cricoid pressure application is acceptable. Gentle face mask ventilation is often necessary to prolong the time to desaturation in critically ill patients who are at greater risk of hypoxemia from primary lung pathology, high metabolic demands, anemia, insufficient respiratory drive, and inability to protect their airway against aspiration [84]. Debate continues as to the efficacy of cricoid pressure in preventing regurgitation [85]. Cricoid pressure-associated complications include airway obstruction leading to interference with manual ventilation, laryngeal visualization, tracheal intubation, placement of supraglottic devices, and relaxation of the lower esophageal sphincter [86]. If used, cricoid pressure should be applied by trained staff (ideally) and released if interfering with mask ventilation, SGA placement, laryngoscopy, or intubation.

**Table 21.2** Intensive care unit rapid sequence intubation care bundle

| | | |
|---|---|---|
| **1.** | **Preintubation: Assemble airway team** | **Who?** |
| 1.1 | Lead nurse (runs preprocedure checklist): Team coordinator | N1 |
| 1.2 | First operator (physician) | O1 |
| 1.3 | Second operator (senior physician who may administer initial drugs) | O2 |
| 1.4 | Cricoid operator (staff nurse; also monitors vital signs on monitor) | N2 |
| 1.5 | Intubator's assistant (second staff nurse) | N3 |
| 1.6 | Manual in-line stabilization operator (additional team member, as appropriate) | M1 |
| **2.** | **Preintubation preparation** | |
| **Checklist commences** (lead by N1 with all team present) | | N1/O2 |
| **This must be read aloud to entire team** | | |
| 2.1 | Reliable intravenous access; time for arterial line? | O1/O2 |
| 2.2 | Capnography on ($EtCO_2$); ensure self-check has completed before induction | N1/O1 |
| 2.3 | Apply full monitoring, if not already | N2/N3 |
| 2.4 | Sit patient 20–25 degree head-up or ramp as appropriate (unless contraindicated) | N2/N3 |
| 2.5 | Chart/bedhead signage/handover communication reviewed: DA or allergy? | O1/TEAM |
| 2.6 | Assess airway | O1/O2 |
| 2.7 | Aspirate gastric tube | N2/N3 |
| 2.8 | Administer oxygen via nasal cannula | N2/N3 |
| 2.9 | Start preoxygenation with NIPPV ($FiO_2$ = 1.0; PEEP = 5–8 cm $H_2O$; PS to $V_T$ of 6 to 8 mL/kg; good mask fit) | N1/N2/N3 |
| 2.10 | Commence 500 mL fluid bolus (unless contraindicated); optimize inotropes | O1/O2 |
| 2.11 | Confirm waters circuit or Ambu bag available for bag-valve-mask ventilation | N1 |
| 2.12 | Yankauer suction working | N1 |

(continued)

**Table 21.2** (continued)

| | | |
|---|---|---|
| 2.13 | Ensure intubation cart with difficult airway equipment is at bedside. If flexible bronchoscope is not on cart, is it immediately available? | N1/O1 |
| 2.14 | Prepare intubation drugs: Hypnotic, relaxant, atropine, bolus pressor/inotrope | O2/O1 |
| 2.15 | Prepare continuous sedation drugs | N2/N3 |
| 2.16 | Confirm sugammadex 16 mg/kg immediately available, if appropriate | N1/TEAM |
| 2.17 | DECISION: If intubation fails, can patient be woken up? | O2 |
| **3.** | **Verbal confirmations** | |
| **Team coordinator asks** | | |
| 3.1 | Operator 2 states intubation plan | O2 |
| 3.2 | Does anyone have any concerns? Opportunity for team to clarify plan | TEAM |
| 3.3 | Has patient been preoxygenated for 3 min? | O1 |
| 3.4 | $EtCO_2$ working? | O1 |
| 3.5 | $EtO_2 > 0.9$ | O2 |
| 3.6 | Can patient be optimized further before induction? | O2 |
| **Team coordinator states checklist complete** | | N1 |
| **4.** | **Intubation attempt** | |
| 4.1 | Optimize head neck: Sniffing position with face parallel to ceiling if possible | O1/O2 |
| 4.2 | Push induction drugs: ketamine 2 mg/kg, rocuronium 1.2 mg/kg, (check no contraindication to succinylcholine, if used) | O2 |
| 4.3 | Cricoid pressure | N2 |
| 4.4 | As face mask removed, ensure nasal cannula flow 15 L/min | N3 |
| 4.5 | Bag ventilation | O1 |
| 4.6 | Intubation | O1 |
| 4.7 | Confirm intubation with waveform $EtCo_2$ | O1/O2 |
| 4.8 | Auscultate both lungs | O1/O2 |
| 4.9 | Cuff pressure 20–25 cm $H_2O$ | N2 |
| **5.** | **Post-intubation care** | |
| 5.1 | Pressor for MAP <70 mm Hg | O1/O2 |
| 5.2 | Initiate sedation | N2 |
| 5.3 | Initiate invasive ventilation: $V_T$ 6–8 mL/kg ideal body weight; PEEP 5 cm $H_2O$; RR 10–20; $FiO_2$ 1.0; Plateau pressure < 30 cm $H_2O$, as appropriate | N2 |
| 5.4 | Recruitment maneuver if stable (CPAP 30 to 40 cm $H_2O$ for 30 to 40 sec) | O2 |
| 5.5 | Chest radiograph and annotate intubation details in medical record | O1/O2 |
| 5.6 | Note tube depth on chart | N2 |
| 5.7 | Arterial blood gas | N2 |
| 5.8 | Titrate $FiO_2$ down to target $PaO_2$ and $V_E$ to target $PaCO_2$ | N2 |
| 5.9 | Complete intubation audit documentation | N1/O2 |

*DA* difficult airway, *$EtCO_2$* end-tidal carbon dioxide, *$EtO_2$* end-tidal oxygen, *NIPPV* noninvasive positive-pressure ventilation, *PEEP* positive end-expiratory pressure, *PS* pressure support, *RR* respiratory rate, $V_E$ minute ventilation; $V_T$ tidal volume

*Use of Neuromuscular Blocking Agents (NMBA)*: Studies of difficult intubations in ICU typically reveal low usage of neuromuscular blockade. However, recent guidelines from the United Kingdom, United States, and Canada for the management of unanticipated difficult airway state unequivocally that if airway management or endotracheal intubation is difficult, further attempts should not proceed without administration of NMBA to abolish laryngeal reflexes, increase chest compliance, and facilitate mask ventilation [87–89]. A recent 2017 Cochrane review reinforces the recommendation for use of neuromuscular blocking agents to improve tracheal intubation conditions [90].

### 21.4.5 Optimizing Oxygenation Preintubation

Critically ill patients are prone to a profound drop in peripheral capillary oxygen saturation ($SpO_2$) due to a combination of intrapulmonary shunt, low mixed venous saturation (as a result of low cardiac output, anemia, and hypermetabolic states), and apnea/hypoventilation [91]. A tight fitting anesthetic-type full face mask must be used for preoxygenation. Beware of leaks around the face mask, evidenced by lack of $EtCO_2$ tracing which is the commonest cause of preoxygenation failure. Correct mask sizing, and using two hands minimizes leaks. Standard non-rebreather face masks only achieve $FiO_2$ of 70% and should not be used. If there is unavoidable leak, the efficacy of mask preoxygenation can be improved by apnoeic oxygenation via nasal cannula at 15 L/min during preoxygenation [92], or as high-flow humidified oxygen (up to 60 L min$^{-1}$) [93] to prolong the safe apnea period. If the $SpO_2$ remains low after 4 min of preoxygenation, this is diagnostic of intrapulmonary shunt [94]. Shunt fractions of 30% cause patients to be highly refractory to simple preoxygenation [95]. Positive end-expiratory pressure (PEEP of 5–10 cm $H_2O$) during preoxygenation is recommended to recruit alveoli [82] but should not exceed the esophageal sphincter pressure (20–25 cm $H_2O$) to avoid gastric distension. Computed tomography studies show that PEEP of 10 cm $H_2O$ during preoxygenation reduces atelectasis from 10% to 2% [96]. The supine position facilitates dorsal lung collapse, so patients should be preoxygenated in the semi-recumbent position or sitting head-up 20 degrees [97]. In critically ill pregnant women, left uterine displacement can prevent aortocaval compression, aid venous return, preserve cardiac output, and maintain utero-placental blood flow.

### 21.4.6 Videolaryngoscopy

Videolaryngoscopy is increasingly becoming standard of care in the ICU as it definitely improves laryngeal view [98, 99]. Videolaryngoscopes generally provide glottic visualization without the need to align the three oropharyngolaryngeal axes due to placement of a camera in the distal third of its blade [100]. This widens the users “eye,” enhancing the view from a conventional 15° to a wider 80° viewing angle, allowing intubators a “look around the corner” which is ideal to aid intubation in the anterior or grade 3–4 larynx encountered not infrequently in obstetrics [101]. A meta-analysis of nine trials of videolaryngoscopy in the ICU showed that it reduced the risk of difficult intubation, the incidence of Cormack and Lehane grade 3 and 4 views, and esophageal intubation and did increase first-pass success [102]. Other advantages include possible reduction of cervical spine movement during intubation [103] and performing an awake intubation with videolaryngoscopy [104], although uncommon. It also allows suctioning of vomitus, blood, and secretions in the airway under direct vision and allows members of the ICU team to view the intubation process and aids communication, allowing adjustment of any misapplication of cricoid pressure and more directed assistance by optimizing backward-upright-right-pressure (BURP) maneuvers without relying on verbal directions from a potentially task-fixated operator during a stressful intubation. A recent Cochrane review however found no evidence that videolaryngoscopy use reduces the number of intubation attempts or the incidence of hypoxia or respiratory complications and may take longer to intubate [105]. This is because device-specific proficiency needs to be gained with each videolaryngoscope; there are channeled and non-channeled videolaryngoscopes with their own subtleties, conventional Macintosh-shaped blades, and angulated blades that need a pre-styletted endotracheal tube in a J-hockey stick shape [106, 107]. Proficiency gained with one device may not be wholly transferable to another, and this impacts the ICU rotational trainee, and even senior supervising doctors who may not have trained in an era of prevalent videolaryngoscopy. Universal adoption of videolaryngoscopy can lead to decay in intubating skills with a direct laryngoscope; one way to counter this is to train using a videolaryngoscope with a conventional Macintosh-shaped blade, and then the device can be used as a direct laryngoscope and the video component used when a direct line of sight is not possible. In summary, videolaryngoscopes should be available in the ICU, and all intensivists should be proficient in their use. If a difficult intubation is suspected, videolaryngoscopy should be used from the outset in keeping with the 2013 guidelines from the American Society of Anesthesiologists (ASA) Task Force on Management of the Difficult Airway [87]. The device should have a screen visible to all team members. It is complementary to direct laryngoscopy (not a replacement) because failed videolaryngoscopy may be rescued with direct laryngoscopy in some instances [108].

### 21.4.7 Confirmation of Tracheal Intubation

Post-intubation, initial confirmation of correct endotracheal tube (ETT) position, involves clinical assessment with a usual insertion depth of 21 cm for females and chest radiography where the ETT tip should be about 5 cm above the carina between the clavicular heads. Waveform capnography confirms that the ETT is in the trachea and remains the gold standard of confirmation and should be routinely used in intubated patients in ICU [82]. The practice of daily chest radiographs should be abandoned and performed only when indicated, the process of obtaining a chest radiograph risks dislodging the ETT, and complications are not reduced by daily films. In the ensuing ICU stay, clinical signs such as chest wall excursion, auscultation, condensation in the endotracheal tube, and $Spo_2$ are unreliable and cannot be used without confirmation by an advanced technique [89]. Advanced techniques include waveform capnography, direct laryngoscopy or videolaryngoscopy confirming ETT in the vocal cords, or flexible scope visualization of the tracheal lumen. The gold standard remains continuous waveform capnography. The NAP4 study in ICU patients [3] revealed that capnography ($EtCO_2$) was not used in 75% to 100% of unrecognized esophageal intubations with most of these patients dying and that lack of capnography materially contributed to 77% of all ICU deaths, including tube displacements. In some cases, when waveform capnography was used, the tracing was misinterpreted, resulting in death [3].

### 21.4.8 Awake Intubation

Awake intubation has advantages of maintaining airway patency and spontaneous ventilation. Awake intubation can be performed via a flexible optical scope, videolaryngoscopy, intubation via an SGA, tracheostomy, cricothyroidotomy, and by retrograde intubation [109]. Its role may be limited in critically ill parturients who need immediate intubation and who may be uncooperative from hypoxia, pulmonary edema, and raised intracranial pressure; all these in itself represent contraindications to awake intubation, including that of an inexperienced operator and absolute patient refusal. Intensivists should beware the significant risk of nasal bleeding if awake nasal intubation is carried out in pregnant patients due to increased vascularity. It is generally recommended to avoid using cocaine as a nasal decongestant as it may interfere with placental blood flow and the systemic effects of vasoconstrictors are potentially hazardous in preeclampsia.

### 21.4.9 Failed Intubation

Airway carts throughout the hospital should be standardized including in the OR, ED, and ICU. Equipment should be purchased with the least experienced potential user in mind, and ICUs must have immediate access to a flexible intubation scope. Should the initial intubation plan fail, the emphasis must be on oxygenating the critically ill parturient. They risk critical hypoxemia, impacting both mother and fetus, with further deterioration of the airway, risk aspiration, and a CICO situation. Declaration of a failed intubation is critical, so the team recognizes this crisis phase and refocuses efforts on how best to assist the airway operator. Human non-technical factors come into play. Pathologic thought processes often occur during airway crises where the operator becomes task-fixated on endotracheal intubation, neglects oxygenation, and loses situational awareness. This hinders them mentally from progressing through the difficult airway algorithms in a timely manner as they fail to appreciate the urgency while endeavoring to intubate the trachea repeatedly.

When intubation attempts fail, nasal high-flow oxygen should continue, and ventilation using a face mask or SGA attempted [87]. Inexperienced ICU residents are better able to oxygenate using SGAs rather than face masks, as this frees up the hands and is less tiring. No more than three SGA insertion attempts should be undertaken to avoid further iatrogenic airway trauma, bleeding, and edema [88]. Second-generation SGAs (with a gastric drain port) are advocated as patient safety is enhanced [110]: they possess higher oropharyngeal seal pressures, thus allowing PEEP and positive pressure ventilation [111]; the improved esophageal seal makes regurgitation of gastric contents less likely; and passing an orogastric tube via the drain tube of the second-generation SGA to empty the stomach and suck out its contents reduces the risk of aspiration [112, 113]. Since the introduction of the LMA ProSeal (considered the first prototype second-generation SGA), others on the market are the LMA Supreme, I-gel, LMA Protector, AES Guardian CPV, LaryngoSeal, Totaltrack VLM, Ambu AuraGain, and air-Q Blocker [114]. In a majority of cases, the SGA provides effective rescue ventilation and oxygenation after failed intubation [115]. If oxygenation through a SGA is successful, then one can either allow the patient to wake up and breathe spontaneously (rarely possible in ICU patients), intubate the trachea through the SGA, or perform invasive tracheal access.

The Intubating Laryngeal Mask Airway (ILMA; LMA North America, San Diego, CA), known as the LMA Fastrach, is an SGA specifically designed to facilitate intubation [116, 117]. However, when faced with a failed intubation, the SGA initially used for rescue is usually one the operator is most familiar with and usually not an ILMA nor one of the newer devices that are also designed to allow guided tracheal intubation, eg. LMA Protector, AMBU AuraGain, I gel, and TotalTrack VLM. Removal of an SGA which is adequately oxygenating an ICU patient during a failed intubation and replacing it with an ILMA is a difficult judgment call and unlikely to occur given the heterogeneity in difficult airway cart devices, lack of availability, or operator inexperience. Most operators would elect to intubate via the working device rather than swap to another with which they are inevitably less familiar.

An extremely useful technique in emergency failed endotracheal intubation is the low-skill fiberoptic intubation [118], or “Laryngeal Mask Airway-Aintree Catheter-Fiberoptic bronchoscope” technique for difficult intubation [119]. An Aintree intubation catheter (AIC; Cook Medical, Bloomington, IN) is mounted on a flexible fiberscope which is then passed through the SGA into the trachea under visualization (minimizing trauma). The flexible fiberscope and SGA are then removed leaving only the AIC in the trachea, after which an endotracheal tube is railroaded in place over the AIC. It proved useful in 128 patients with a 93% success rate; most had Cormack-Lehane grade 3 or 4 views, and some could not be ventilated via face mask [119]. If intubation is impossible and critical hypoxia develops, it is possible to oxygenate via the AIC provided there is a path for air to escape, but barotrauma is a real risk [120].

### 21.4.10 Emergency Invasive Airway Access

We should be mindful that not every CICO situation occurs out of nowhere. A prompt decision to perform emergency invasive airway access needs to be made and determines outcomes because the natural evolution of an airway crisis is first difficulty, trauma, swelling, and bleeding/aspiration progressing to complete obstruction (all largely iatrogenic). Emergency airway access can be achieved by one of three techniques: surgical incision with a scalpel, narrow cannula-over-needle, or large bore cannula (usually ≥4 mm) over a wire or trocars [121]. A small bore/needle technique is a temporary airway with a high failure rate, prone to kinking and displacement, whereas a simple surgical technique has a high success rate and results in a cuffed tube in the trachea that allows the continuation of ventilator treatment. A surgical technique must be mastered by all emergency airway providers and should be considered the default technique [121, 122].

## 21.5 Conclusion

The anatomic and physiological changes of pregnancy make management of the airway in obstetric patients particularly treacherous. Critically ill pregnant women with cardiopulmonary or hemodynamic compromises, with the fetus(es) that may or may not be imminently delivered, are further physiologically compromised. They have significant V/Q abnormalities and lower FRCs: preoxygenation is less effective, and apnea is poorly tolerated. Pregnant patients are frequently unfasted, have delayed gastric emptying, and may require urgent intubation without time for assessment or preparation. Dedicated guidelines on tracheal intubation in critically ill adults were recently published in 2018 and provide welcome direction and comprehensive management strategies [122]. Thorough preoxygenation, use of videolaryngoscopes, an intubation checklist incorporating a modified RSI, and post-intubation continuous waveform capnography are key.

Successful airway management requires training of a well-formulated airway plan, known to the entire team, using equipment familiar to the team members. The first intubation attempt is always the best; attention should be paid to denitrogenation of the lungs, patient positioning (head ramped), left uterine displacement, skilled assistance, using neuromuscular blocking agents, and the release of cricoid pressure if it impedes glottic exposure when performing a rapid sequence endotracheal intubation. Failed intubation after three optimal laryngoscopy attempts should invoke the failed intubation drill, remembering that oxygenation and ventilation takes priority over intubation. A SGA with gastric access port is recommended as the preferred rescue airway strategy. A CICO situation calls for early rescue by cricothyrotomy/surgical airway. No singular airway device improves outcomes: the emphasis is on adequate training, supervision, and experience in airway management; good assessment and backup planning; using RSI intubation bundles, checklists, and standards of practice to minimize procedural difficulty; using airway equipment with which the doctor has practiced and is familiar with, with the immediate availability of appropriate rescue devices and deployment of the most appropriate rescue techniques when airway management fails; these strategies are amenable to ongoing training and simulation drills to optimize human factors and enhance teamwork for improving care of the critically ill parturient.

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