General anesthesia in the parturient

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Airway management in the pregnant woman presents unique challenges due to anatomic and physiological changes in pregnancy, situational factors including urgency of surgery and isolated location, and lack of training opportunities because of the reduced number of obstetric general anesthetics. In addition, the presence of the fetus means that severe hypoxia during difficult airway management can potentially compromise 2 lives and creates a potential conflict between the needs of the mother and the fetus. Rapid sequence induction (RSI) with cricoid force (CF) and tracheal intubation for obstetric general anesthesia (GA) is considered the gold standard. The recently published Obstetric Anaesthetists Association/Difficult Airway Society (OAA/DAS) difficult airway guidelines emphasize the need for good planning, preparation, and effective team communication before performing RSI to ensure a good outcome for the mother and the baby.[1]

Morbidity and mortality

After the introduction of the Confidential Enquiry into Maternal Deaths program in England and Wales in 1952,[2] failed intubation and aspiration during the administration of GA were identified as the leading causes of anesthesia-related maternal morbidity and mortality. This led to the increased use of neuraxial anesthetic techniques to attempt to reduce airway-related complications. The number of cesarean deliveries (CDs) is increasing with an average global rate of 18.6%, and an average annual increase rate of 4.4% from 1990 to 2014.[3] In a recent survey in the United States, it is estimated that only 6% of CD are performed under GA.[4]

Anesthetic-related maternal mortality has decreased, which is partly due to the use of regional anesthesia (RA) and better training, staffing, and facilities. In the UK, 50 obstetric deaths related to anesthesia were reported from 1964 to 1966 in comparison with just 1 from 2015 to 2017.[2] The case fatality risk ratio between general and regional techniques in obstetrics has reduced from 16.7 between 1985 and 1990 to 1.7 between 1997 and 2002.[5] This should not underestimate the potential for GA to cause significant morbidity and mortality, particularly when compared with the nonpregnant population. The risk of failed intubation remains higher in parturients, ranging from 1:390 to 1:443 when compared with that of the general population (1:1000 to 2000).[6,7] Similarly, maternal mortality from failed intubation is ~2.3 per 100,000 GAs for CD (1 death per 90 to 102 failed intubations) compared with 0.6 per 100,000 GAs for the general population. In addition, the use of emergency cricothyrotomy is 3.4 per 100,000 in parturients as compared with 2 per 100,000 in nonpregnant patients.[7,8]

Aspiration of gastric contents is a risk associated with GA. In the Fourth National Audit Project (NAP4), the largest study in the UK of complications of airway management, almost a quarter of the reported cases involved aspiration, and more than half of the airway-related deaths were directly related to aspiration.[8] The pregnant woman is considered to be at higher risk of aspiration because of the physiological changes of pregnancy. Fortunately, the incidence of aspiration is very low at 2 per 10,000 GAs.[9]

Data from the Fifth National Audit Project (NAP5), a study that evaluated accidental awareness under general anesthesia (AAGA),[10] suggest that its incidence is infrequent (1:19,000 anesthetics), but there was an overrepresentation of obstetric cases (1:1200), with most of them occurring during a CD (1:670). The higher incidence of AAGA in the obstetric population is related to multiple factors that include emergency nature of the surgery, drug errors, and inadequate dosing possibly related to the higher use of sodium thiopental as the induction agent, female sex, RSI, omission of opioids, increased incidence of difficult airway, and reduced doses of volatile anesthetic agents to avoid neonatal depression and postpartum hemorrhage (PPH).[11] Irrespective of the possible reasons for this disparity, emphasis should be given to the prevention of AAGA by providing appropriate training and developing strategies to mitigate the long-term effects of AAGA to the mothers, such as posttraumatic stress disorder and fear of future anesthesia and surgery.[12]

An additional risk for women who have a GA for CD is the higher risk of developing PPH, which is considered to be partly related to the uterine relaxant effects of volatile anesthetic agents.[13,14]

Despite these associated risks, a Cochrane review did not demonstrate superiority of RA over GA in terms of major maternal or neonatal outcomes.[15] Although this review suggested that more women in the GA group were satisfied with their anesthetic and they would choose the same in the future, our approach to the choice of anesthesia has not altered significantly and the use of GAs in obstetric practice remains low.

Preoperative planning and preparation

The recently published OAA/DAS obstetric difficult airway guidelines include an algorithm for the "Safe obstetric general anesthetic" (Fig. 1)[1] that supports a safe approach to GA in the obstetric patient. This algorithm emphasizes preoperative preparation to include airway assessment, fasting, and antacid prophylaxis, and intrauterine fetal resuscitation when appropriate.

Airway assessment and anticipated difficult airway

Airway assessment should be performed and documented in all patients before administering an anesthetic. Studies have shown

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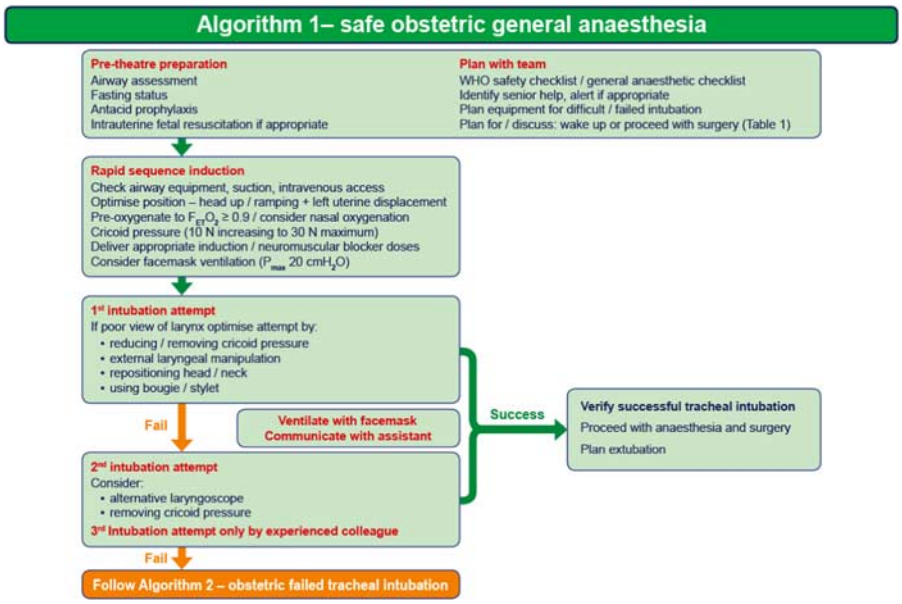

Figure 1. Obstetric Anaesthetists Association/Difficult Airway Society (OAA/DAS) obstetric difficult airway guidelines. Algorithm 1—Safe obstetric general anesthesia. Table 1 in the algorithm refers to OAA/DAS Obstetric Difficult Airway Guidelines—Table 1—proceed with surgery? shown in Figure 4. $F_{ET}O_2$ indicates end-tidal oxygen fraction; WHO, World Health Organization. Reproduced from Mushambi et al,[1] with permission from Obstetric Anaesthetists' Association/Difficult Airway Society. Copyright Obstetric Anaesthetists' Association/Difficult Airway Society, 2015, London, UK. All permission requests for this image should be made to the copyright holder. full color online

this is not always achieved, particularly in obstetric practice, where airway assessment documentation was found to be lacking in ~40% of cases.[16] The ability to accurately predict a difficult airway allows for the planning, preparation, and management of a potentially difficult airway. Unfortunately, bedside tests such as the Mallampati score, oral aperture, thyromental distance, neck extension, and mandibular protrusion have low predictive values when used in isolation. A Cochrane review concluded that individual bedside tests fail to detect a large proportion of difficult airways.[17] Despite being one of the more popular bedside tests, the Mallampati grading has low sensitivity (42% to 81%), specificity (53% to 89%), and positive predictive values (2% to 21%).[18] However, when bedside tests are used in combination, the chances of predicting a difficult airway increase.[19–22] In obstetric practice, airway assessment is often hindered by the limited time available to assess the airway in an emergency. To address this, all opportunities such as anesthetic antenatal assessment clinics and at the establishment of epidural analgesia in labor should be utilized to assess the airway and document the findings.

Airway assessment should look beyond simply assessing for difficult intubation but also include assessment of the ability to ventilate with a face mask[23]; insert and ventilate with a supraglottic airway device (SAD), obtain an adequate view with laryngoscopy, intubate the trachea and ventilate the lungs, obtain front of neck access (FONA), and extubate the trachea safely.[1] Factors associated with a difficult airway include increased body mass index $>35\ kg/m^2$, neck circumference of $>50\ cm$, thyromental distance $<6\ cm$, reduced mouth opening $<4\ cm$, Mallampati score 3 to 4, fixed cervical spine flexion deformity, poor dentition or buck teeth, obstructive sleep apnea, reduced lower jaw protrusion, and airway edema.[1] Despite all this, predicting a difficult airway is challenging.

In addition to bedside tests for airway assessment, the use of ultrasound is gaining popularity. Identification and marking of the cricothyroid membrane before induction of GA are useful, particularly in patients with a concerning airway.[24,25]

A pregnant woman with a predicted or known difficult airway should be referred antenatally for an anesthetic evaluation to assess the airway and formulate a delivery plan with the obstetrician (Fig. 2). The plan should recognize and acknowledge that the woman may present for surgery at an unpredictable time at any gestation. In a recent literature review describing the management of 158 pregnant women with an anticipated difficult airway,[26] the authors found the technical aspects of airway management of a pregnant woman with anticipated difficult airway to be similar to the nonpregnant patient. However, the unpredictable nature of a CD can make airway management more difficult. The review presented guidance on the decision of the timing and mode of delivery based on the patient's clinical characteristics (including airway pathology, obstetric history, the feasibility of neuraxial block, potential need for GA or awake tracheal intubation), availability of airway equipment, and experienced personnel to provide safe airway management at all times. An elective CD may be considered to ensure that safe airway management is provided by experts during normal working hours. If vaginal delivery is chosen as the mode of delivery, it is recommended to utilize epidural analgesia unless it is contraindicated and ensure a reliable catheter so that it can be used as the primary anesthetic if CD is necessary. When possible, it is best to avoid any emergent surgical intervention to allow time to establish a safe anesthetic.

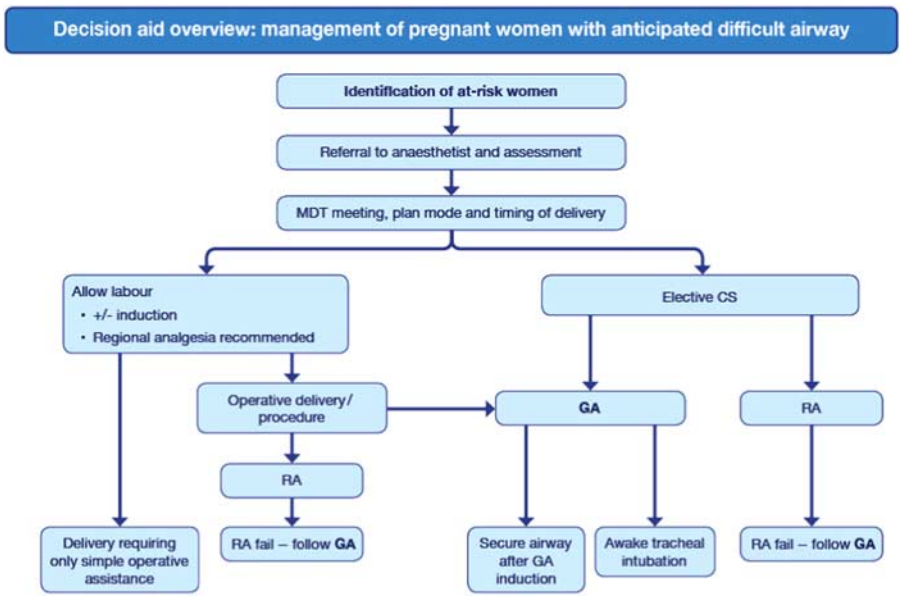

Figure 2. Decision aid overview of the management of the anticipated difficult airway in obstetrics. CS indicates cesarean section; GA, general anesthesia; MDT, multidisciplinary team; RA, regional anesthesia. Reproduced from Mushambi et al,[26] with permission from John Wiley and Sons. full color online

Although RA is the preferred technique to avoid airway manipulation, GA may be necessary for multiple reasons such as failed or inadequate RA or major hemorrhage. If GA is required, a decision must be made between securing the airway after induction of GA or performing an awake intubation. Awake tracheal intubation with either a flexible bronchoscope, a direct laryngoscope, a video laryngoscope, SAD, or FONA may be the safest options if difficult or impossible mask ventilation is anticipated. The recently published DAS guidelines on awake tracheal intubation provide a comprehensive description of the planning, preparation, and performance of awake tracheal intubation.[27]

Fasting and aspiration prophylaxis

Gastric emptying in the nonlaboring pregnant woman is the same as in the nonpregnant patient.[28] Therefore, perioperative fasting guidelines for elective surgery for pregnant women are similar to those for nonpregnant women, allowing clear fluids up to 2 hours and a light meal up to 6 hours before an elective operation.[29,30]

Labor and opioid analgesia delay gastric emptying, especially of food; hence, women in labor are arbitrarily considered to have a full stomach and are often not allowed to eat during labor to reduce the risk of aspiration should they need a CD under GA. The beneficial effects of asking women to fast in labor are uncertain, and some argue that unnecessary fasting may have undesired effects on maternal satisfaction.[31] However, in a study that randomized parturients into having a light diet or only water during labor, those women who ate had significantly increased residual gastric volumes.[32] In their most recent guidelines, the American Society of Anesthesiologists continue to restrict eating during labor.[33] In the UK, the national guidance stratifies women into low and high risk based on the perceived risk of requiring a GA. Low-risk women are allowed a light diet, whereas high-risk women are limited to drinking clear liquids.[34]

Assessing gastric content status can be challenging particularly in the "nonfasted" obstetric patient who needs an emergency CD under GA. Preoperative gastric ultrasound is gaining recognition as a useful method to quantify gastric contents, and it may add valuable information in pregnant women. A standardized framework of the technique has been proposed in nonpregnant patients.[35] In the pregnant woman, the general principles remain the same, but technical challenges arise due to the gravid uterus. The presence of thickened food with an antral cross-sectional area (CSA) $> 608\ mm^2$ (or CSA $> 505\ mm^2$ with visible fluid in the antrum) with the patient in the semi-recumbent position and a CSA $> 960\ mm^2$ in the right lateral semi-recumbent position should be considered as high risk for aspiration and warrant further actions such as delay delivering with a GA if possible.[36] This is an evolving field and further research is warranted to develop decision-making strategies and incorporate its use into everyday clinical practice.

The prophylactic use of antacids, H2-receptor antagonists, proton pump inhibitors (PPIs), and prokinetic drugs aims to reduce the volume and increase the pH of gastric contents and minimize the risk of regurgitation and aspiration. A combination of prophylactic agents might be more effective than single medication.[37]

Randomized-controlled trials have indicated that H2-receptor antagonists such as ranitidine [50 mg intravenously (IV) and 150 mg orally] and famotidine (20 mg IV) administered before surgery are associated with higher gastric pH. These should be administered in a timely manner as they require 30 to 120 minutes after IV and oral administration, respectively, to be maximally effective.[38,39] However, in October 2019, the Medicines and Healthcare products Regulatory Agency instructed the withdrawal of ranitidine in the UK because N-nitrosodimethylamine, a compound classified as a probable human carcinogen, was found in some oral ranitidine products and recommended the use of PPIs such as omeprazole 20 mg orally instead.[40,41] The European Medicines Agency is currently evaluating data to assess whether patients using ranitidine are at any risk from N-nitrosodimethylamine.[42] The American Society of

Anesthesiologists also list PPIs, for example, pantoprazole 40 mg IV, for consideration.[29] Metoclopramide 10 mg IV can be used in addition to H2-receptor antagonists or PPIs, but it is more effective as an antiemetic.[43] Nonparticulate antacids such as sodium citrate (30 mL) increase gastric pH immediately and for ~1 hour and therefore should be administered shortly before induction of GA.[37,44,45]

Consent

Pregnant women should be offered evidence-based information to make informed decisions about their anesthetic care and treatment. Discussing labor analgesia early in the antenatal period allows the woman to have informed consent before the onset of labor or an elective procedure. In the UK, the Montgomery v Lanarkshire's case in March 2015 highlighted the importance of following the correct consent process.[46,47] In this case, a diabetic woman argued that she would have proceeded with CD if she had been better informed of her exceedingly high risk of shoulder dystocia. The courts found in her favor. It is therefore essential that women are informed of the different options of labor analgesia and anesthesia and the advantages and disadvantages of each option.[48]

Planning with the team

Team briefing is an opportunity for team members to introduce themselves and discuss anticipated safety concerns. Preoperative team briefing should involve as many members of the team as possible, including obstetricians, anesthesia providers, midwives, surgical technicians, nurses, and pediatricians, as it helps to increase situational awareness during the procedure, promote operating room efficiency, improve teamwork and job satisfaction, and ultimately provide a safer operating room environment.[49,50] It should be held in a discreet area where noise is minimal, and patient confidentiality can be maintained.

Checklists

Checklists, including the World Health Organization (WHO) surgical safety checklist, have recently been introduced into clinical practice to reduce human error through good preparation, team communication and planning, and rapid identification of potential difficulty. The use of a checklist in acute and nonacute situations has been associated with a reduction in complications.[51,52] Obstetric-specific checklists such as the one shown in Figure 3 are a more recent addition, and their use is gaining popularity.[52,53] This checklist is designed to be used verbally when preoxygenation is underway; the anesthetic assistant or another member of the operating room team reads it aloud, and the anesthesiologist responds. When time allows, it is a useful reminder of the vital steps during RSI including who and how to call for help should it be needed and outlining the proposed plan should a difficult airway be encountered. A checklist to assist with RSI in a patient with coronavirus disease 2019 (COVID-19) has recently been published and is easily adaptable for local use.[54]

Management of failed intubation

Good communication in the operating room is imperative, and where time allows, the team discussion before induction of GA

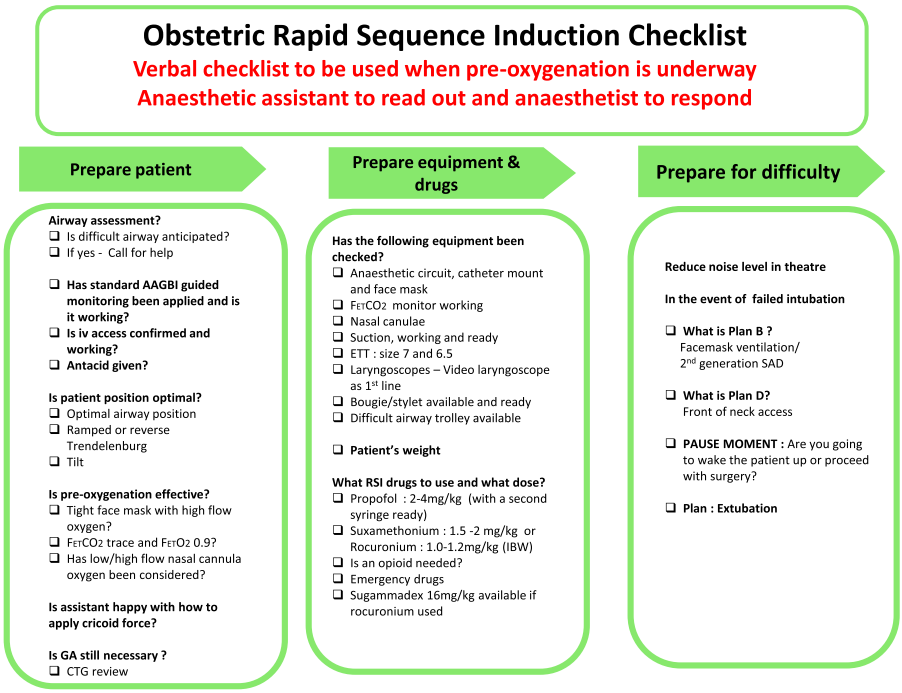

Figure 3. Obstetric RSI checklist. Designed by R.K. and M.C.M. for University Hospitals of Leicester NHS Trust, Leicester, UK. AAGBI indicates Association of Anaesthetists of Great Britain and Ireland; CTG, cardiotocograph; ETT, endotracheal tube; $F_{ET}CO_2$, end-tidal carbon dioxide fraction; $F_{ET}O_2$, end-tidal oxygen fraction; GA, general anesthesia; IBW, ideal body weight; RSI, rapid sequence induction; SAD, supraglottic airway device. Modified from original by Wittenberg et al[53] with permission from Elsevier. Adaptations are themselves works protected by copyright. So in order to publish this adaptation, authorization must be obtained both from the owner of the copyright in the original work and from the owner of copyright in the translation or adaptation. full color online

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 • Critical cardiac or respiratory compromise, cardiac arrest
	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 • Fetal haemorrhage • Suspected uterine rupture
	Anaesthetist	• Novice	• Junior trainee	• Senior trainee	• Consultant / specialist
	Obesity	• Supermorbid	• Morbid	• Obese	• Normal
	Surgical factors	• Complex surgery or major haemorrhage anticipated	• Multiple uterine scars • Some surgical difficulties expected	• Single uterine scar	• No risk factors
	Aspiration risk	• Recent food	• No recent food • In labour • Opioids given • Antacids not given	• No recent food • In labour • Opioids not given • Antacids given	• Fasted • Not in labour • Antacids given
	Alternative anaesthesia • regional • securing airway awake	• No anticipated difficulty	• Predicted difficulty	• Relatively contraindicated	• Absolutely contraindicated or has failed • Surgery started
After failed intubation	Airway device / ventilation	• Difficult facemask ventilation • Front-of-neck	• Adequate facemask ventilation	• First generation supraglottic airway device	• Second generation supraglottic airway device
	Airway hazards	• Laryngeal oedema • Stridor	• Bleeding • Trauma	• Secretions	• None evident

Figure 4. Obstetric Anaesthetists Association/Difficult Airway Society (OAA/DAS) Obstetric Difficult Airway Guidelines—Table 1—proceed with surgery? Criteria to be used in the decision to wake or proceed after failed tracheal intubation. In any individual patient, some factors may suggest waking and others proceeding. The final decision will depend on the anesthetist's clinical judgment. Reproduced from Mushambi et al,[1] with permission from Obstetric Anaesthetists' Association/Difficult Airway Society. Copyright Obstetric Anaesthetists' Association/Difficult Airway Society, 2015, London, UK. All permission requests for this image should be made to the copyright holder. full color online

should include whether to wake the mother or proceed with the CD in the event of failed intubation. The OAA/DAS difficult airway guidelines highlight the many factors that need to be considered in this decision (Fig. 4).[1] Seven of the 9 factors are present before the induction of GA, which provides the opportunity to have a provisional decision before failed intubation occurs. The final decision is made after failed intubation occurs and is influenced by factors relating to the woman, fetus, and clinical situation with the exact combination unique to each patient. It is essential to recognize that the final decision to wake or proceed will be made during a very stressful time and, human factors and situational awareness will influence the actions taken by the anesthesia provider at that time.

RSI

Position

Proper positioning during RSI can improve airway management and maximize the chances of successful intubation. A head-up position should be considered in addition to lateral uterine displacement. A 30-degree head-up position increases functional residual capacity in pregnant women,[55] decreases the impingement caused by large breast, improves laryngoscopy view, and may reduce gastroesophageal reflux.[56,57] A 20- to 30-degree head-up position has been shown to increase the duration of nonhypoxic apnea in nonpregnant obese and nonobese patients.[58–61]

Preoxygenation and apneic oxygenation

Pregnant women have reduced functional residual capacity and increased oxygen requirements, which places them at risk of rapid desaturation during apnea. Effective preoxygenation with a tight-fitting face mask and to an end-tidal oxygen fraction of > 90% may prolong time to desaturation. However, moderate hypoxemia (SpO_2 < 95%) and severe hypoxemia (SpO_2 < 90%) were observed in up to 20% and 9.4%, respectively, of pregnant women during RSI for emergency CD.[62] Therefore, additional measures are necessary to prevent maternal hypoxia during RSI. Mask ventilation during RSI has historically been discouraged because of the fear of gastric insufflation and the resultant increased risk of aspiration.[63] However, recent studies show that if the peak inspiratory pressures during mask ventilation are reduced to a maximum of 20 cm H_2O and that there is an effective and correct application of CF, gastric insufflation is not a risk.[64,65] Therefore, gentle mask ventilation after administration of a neuromuscular blocking agent is permissible to allow oxygen delivery during apnea and before intubation. In some women, particularly obese parturients, desaturation can still occur during intubation, especially if difficult intubation is encountered. Apneic oxygenation using low-flow oxygen via nasal cannulae (5 to 15 L/min) has been shown to increase safe apnea time in nonpregnant obese patients, and it is recommended as a simple means of oxygenating pregnant women during apnea.[66,67] There is evidence that high-flow humidified nasal oxygenation (HFHNO) (60 L/min) may be used for preoxygenation and to provide apneic oxygenation during RSI in nonpregnant patients.[68] Recent work has shown that HFHNO may not be as effective as mask preoxygenation in pregnant women when assessed by measuring end-tidal oxygen levels. However, these studies did not investigate its use for apneic oxygenation in pregnant women.[69–72] The use of HFHNO for preoxygenation is more efficient in prolonging the safe apnea period, and it may reduce the stress associated with desaturation during difficult intubation, which can have a positive impact on human factors.[68] Peri-intubation oxygenation using apneic oxygenation is a concept to consider when intubating a parturient.

Induction and neuromuscular blocking drugs

Although propofol is now used routinely for RSI in Obstetrics in the United States, in the UK, thiopental remains a popular induction agent despite concerns such as unfamiliarity with its use, higher risk of drug errors, and the inconvenience of the need for premixing before use.[73] There have been some concerns over the effects of propofol on neonatal outcomes. A meta-analysis in 2018 investigating the effects of hypnotic agents used for RSI for women having CD found that induction with thiopental resulted in higher umbilical arterial pO_2 than propofol.[74] No other differences in any of the other primary outcomes were found when comparing thiopental with propofol. There are now strong recommendations to use propofol instead of thiopental,[75,76] and on balance, propofol should now be the preferred induction agent for routine use. Other induction agents that are used less frequently are ketamine and etomidate, but these are often reserved for specific situations such as hemodynamically compromised patients.

Suxamethonium is the most commonly used muscle relaxant during RSI in the UK despite its well-recognized side effects and disadvantages, including the greater risk for perioperative anaphylaxis.[77] The Sixth National Audit project, the largest prospective study of anaphylaxis related to anesthesia and surgery, confirmed that this risk is almost double with suxamethonium than any other neuromuscular blocking agent, with an incidence of 11 life-threatening allergic reactions per 100,000 exposures.[78] Rocuronium may be a better alternative as it has been associated with slower desaturation and faster recovery of SpO_2 than suxamethonium when used in overweight patients[79] and faster surgical access with better surgical conditions for fetal delivery.[80] A dose of 1 to 1.2 mg/kg is needed to provide comparable intubating conditions to suxamethonium,[81] but these doses have not been studied thoroughly in pregnant women having CD, and hence are not recommended by the manufacturer.[82] The only randomized-controlled trial that examined the fetal effects of a maternal dose of rocuronium 1 mg/kg in CD showed that rocuronium was associated with lower 1-min Apgar scores compared with patients who received suxamethonium but there was no difference in 5-, 10-min Apgar scores and umbilical cord blood gases.[83] The clinical significance of the lower 1-min Apgar scores is uncertain and warrants further investigation. In case of failed intubation after the administration of rocuronium 1 to 1.2 mg/kg, high doses of sugammadex (16 mg/kg) can restore the maternal neuromuscular function faster than spontaneous recovery after the administration of suxamethonium.

The use of opioids during RSI for CD has been associated with potential neonatal depression. Therefore, their use has been reserved for cases such as severe preeclampsia and maternal cardiac disease, where it is vital to obtund sympathetic stimulation during laryngoscopy and intubation.[84] These adverse outcomes are mostly associated with the use of longer-acting opioids. For example, a recent meta-analysis found no significant effect on Apgar scores, neonatal airway interventions, and neonatal intensive care unit admissions when shorter-acting opioids such as remifentanil and alfentanil are used.[85]

CF

Since its introduction by Sellick in 1961, CF has been widely and routinely used to occlude the upper esophagus and reduce the incidence of regurgitation and aspiration during RSI, but it also remains an area of continuing controversy and ongoing debate. Over the years, the use of CF has been associated with a reduction in maternal morbidity and mortality from GA.[86] However, recent studies, such as the IRIS Trial, failed to show any reduction in the incidence of pulmonary aspiration when CF was compared with a sham procedure in the nonobstetric population.[87] In addition, the CF group in this study had worse laryngoscopy views and required more intubation attempts, suggesting that CF adversely affects laryngoscopy and intubation. Surveys have demonstrated the lack of knowledge and the improper application of the technique by operating room staff.[88,89] In a prospective study, consultant anesthesiologists failed to successfully locate the cricoid cartilage using a landmark approach in 60% of the women undergoing GA for CD.[90] In situations where the cricoid cartilage is difficult to identify, the use of ultrasound can aid in identifying its location correctly.[91]

The concerns about the efficacy of CF are reflected in the American Heart Association (AHA) cardiopulmonary resuscitation guidelines that advise against the routine use of CF during cardiac arrest.[92] Although the OAA/DAS guidelines for the management of difficult and failed tracheal intubation in obstetrics continue to recommend the use of CF, they advise for a low threshold to reduce or remove CF if any difficulties are encountered during intubation.[1]

Gautier et al[93] compared the effects of CF against an alternative technique in which force was applied to the lower left paratracheal esophagus (Fig. 5). This study showed a significant decrease in the esophageal diameter when the latter approach was used, and more importantly, it was more effective than CF in reducing the air entry into the gastric antrum during face mask ventilation. This novel maneuver has not been validated in obstetrics, but some authors advocate its use as an alternative to CF in the obstetric population.[94]

Laryngoscopy

To minimize the number of attempts at intubation and hence reduce airway trauma, it is crucial to maximize the chances of successful intubation at first attempt. The choice of laryngoscope can impact successful intubation rates. There is evidence to show that, provided that the anesthetist is appropriately trained, video laryngoscopes offer better laryngeal views, have higher rates of successful tracheal intubation, and are a better teaching tool than traditional direct Macintosh laryngoscopes. Therefore, video laryngoscopes should now be used as the first-line choice during obstetric RSI.

Failed intubation

If, after 2 attempts, intubation is unsuccessful, failed intubation should be declared and help should be sought immediately. The priority is to deliver oxygen to the patient using either a SAD or via face mask ventilation. A second-generation SAD with a gastric drainage is the preferred device as it provides added protection against aspiration and gives a better seal of the airway. Placement of the SAD should be limited to 2 attempts to minimize trauma to the airway, and CF should be released to allow for successful placement. If face mask ventilation is used, CF may also need to be released, and a 2-handed technique may be required to aid ventilation.

If adequate oxygenation cannot be obtained using either a SAD or face mask, laryngeal spasm must be excluded by adequate neuromuscular blockade before declaring a "cannot intubate cannot oxygenate" situation and performing FONA. The Difficult Airway Society recommends using a scalpel-bougie-tube cricothyroidotomy

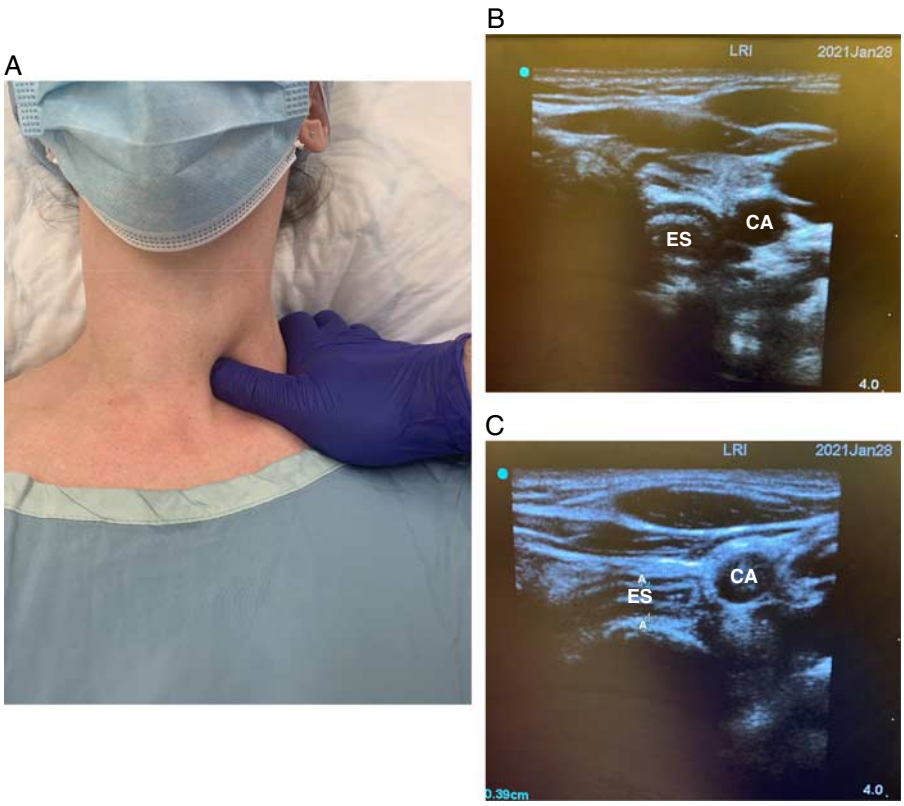

Figure 5. Application of low left paratracheal pressure (A) on the esophagus (as described by Gautier et al[93]). Ultrasound images demonstrating the esophagus (B) and compression of the esophagus (C) by applying pressure with the probe in the transverse plane, just cephalad to the suprasternal notch. CA indicates carotid artery; ES, esophagus. full color online

as the technique of choice for FONA.[95] If attempts to oxygenation using FONA fail and a cardiac arrest occurs, a perimortem CD needs to be carried out within 4 minutes of the cardiac arrest as part of the maternal resuscitation process.[96]

If, however, oxygenation is successful with a SAD, face mask, or FONA, a combined obstetric and anesthetic decision on whether to proceed with surgery or wake the woman up is necessary. There is an increased risk of neonatal admission to the neonatal intensive care unit, and therefore, the neonatal team should be present at the time of delivery.[97]

The OAA/DAS guidelines describe how to manage the patient on either path of waking the patient up or proceeding with surgery (Fig. 6).[1] If the patient is woken, awake securement of the airway should be performed and securing the airway after induction of GA should ideally be avoided. If surgery is continued with the use of unsecured airway using SAD, oxygenation is best achieved with neuromuscular paralysis and controlled ventilation. When proceeding with an unsecured airway, the anesthesiologist should plan and prepare for FONA in case it becomes difficult to oxygenate the patient as well. Fundal pressure during the delivery of the baby should be reduced or avoided to minimize regurgitation and aspiration.

Extubation

Extubation of the trachea in the obstetric patient should follow routine guidance as provided by DAS guidance following their high-risk algorithm (Fig. 7) as obstetric patients have a potentially difficult airway in addition to the higher risk of aspiration.[98] In the UK, NAP4 showed that almost a third of all adverse airway events, associated with anesthesia, occurred at the end of surgery and in recovery.[8] Similar concerns were raised in the United States where 5 of the 8 anesthesia-related deaths over an 18-year period resulted from airway obstruction or hypoventilation during emergence or in the recovery unit.[99]

Another concern is that of awareness during emergence. Almost a fifth of the reports received by NAP5 occurred during emergence, and 85% of these patients experienced the distress of paralysis while awake.[10] The vast majority of these cases were potentially preventable with appropriate use of a nerve stimulator, better communication, and maintenance of anesthesia until full reversal of neuromuscular blockade.

Teaching and training

The reduced number of obstetric GAs means that anesthesiologists are exposed to fewer GAs in their training. In 2001, a survey found that 13% of the US anesthesia residents had not performed a GA in a term parturient during their training.[100] Given that obstetric anesthesiologists will continue to resort to GA, either when a regional block is contraindicated or when the urgency of the situation does not allow adequate time for it, alternative training methods need to be adapted to ensure patient safety. Simulation is becoming an integral part of modern medical training as it has been shown to improve teamwork,

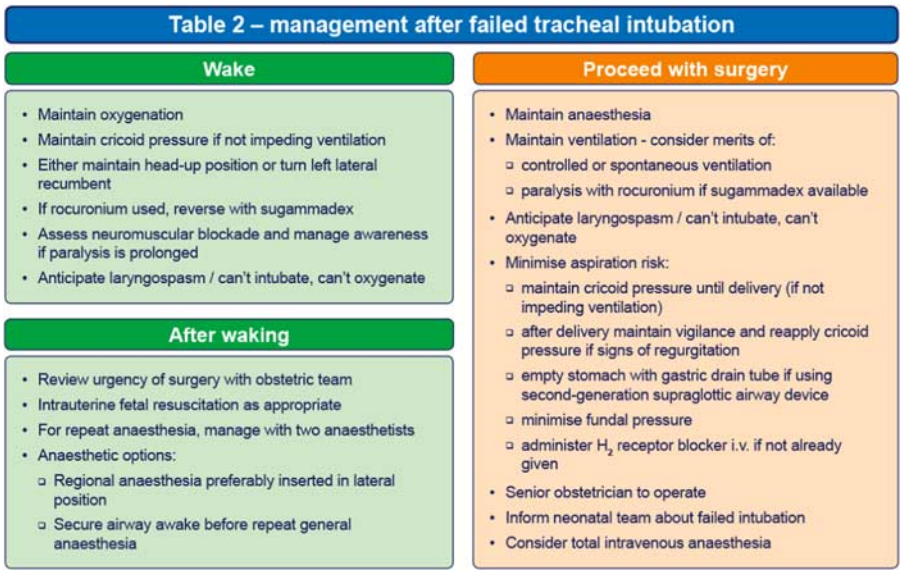

Figure 6. Obstetric Anaesthetists Association/Difficult Airway Society (OAA/DAS) Obstetric Difficult Airway Guidelines—Table 2—management after failed tracheal intubation. Reproduced from Mushambi et al,[1] with permission from Obstetric Anaesthetists' Association/Difficult Airway Society. Copyright Obstetric Anaesthetists' Association/Difficult Airway Society, 2015, London, UK. All permission requests for this image should be made to the copyright holder. full color online

communication skills, and skill performance. Human factors and nontechnical skills are as important as clinical skills in the management of a difficult airway.

Debriefing after a GA is an alternative method of carrying out multidisciplinary teaching. It brings together the team after the procedure or event to discuss in a nonthreatening manner what the team did right and identify areas of improvement. It is a reflective exercise and is a step toward building up the morale of the team, especially when things might not have gone well. "Hot" debriefing occurs immediately after a clinical event, and it has the advantage of earlier intervention, improved participation, and improved recall of events.[101] "Cold" debriefing should be carried out within 2 weeks after the incident. The After Action Review process is a useful, structured approach to undertaking a debrief and constructive way of identifying lessons from the incident.[102]

Future

Use of SADs for GA for CD

RSI and tracheal intubation are considered the gold standard for airway management in pregnant women because of the perceived

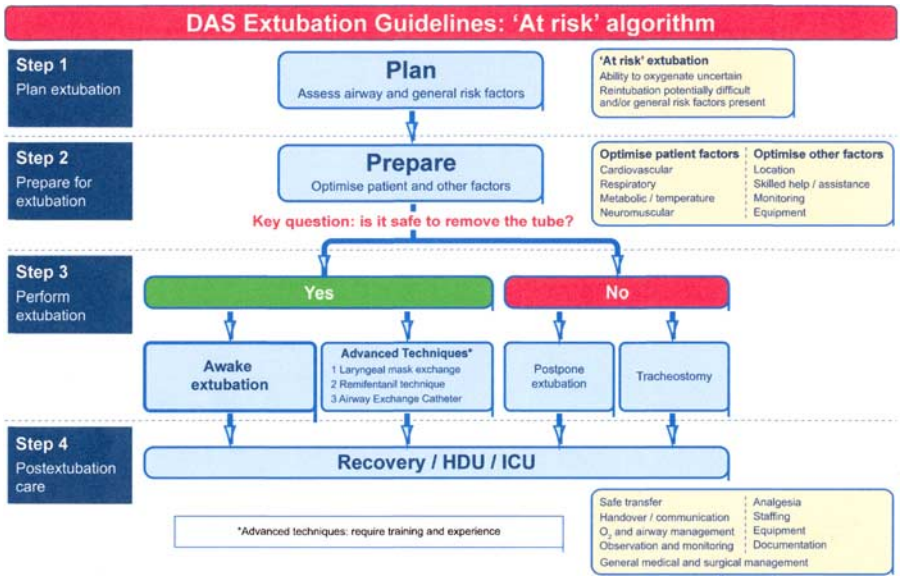

Figure 7. Difficult Airway Society (DAS) Extubation Guidelines—Extubation "at risk" algorithm. Reproduced from Popat et al,[98] with permission from the Difficult Airway Society. HDU indicates high dependency unit; ICU, intensive care unit. full color online

increased risk of regurgitation and aspiration during pregnancy. Since the 1990s, there has been a gradual increase in the use of SAD as a means to continue anesthesia for CD when failed intubation occurs.[7] Since 2001, the use of the SAD as the primary airway device for GA for CD has been demonstrated in several studies[103–113] and evaluated in a recent editorial.[114] Although most of the studies excluded obese and nonfasted patients, to some surprise, a few included nonfasted patients undergoing emergency CD.[114] In the few studies that were randomized, there were more problems in the tracheal intubation group compared with SAD groups such as failed intubation and laryngeal spasm at extubation.[114] Of the 8000 patients who have now been studied so far, there has been one report of regurgitation (during the application of fundal pressure) and no reported cases of aspiration.[114] However, failure to report any incidence of aspiration during the use of a SAD as the primary airway device may reflect the lack of sufficiently powered studies to investigate the risk of aspiration as the primary outcome.

In addition, there is debate on whether all pregnant women undergoing GA should be considered at higher risk of aspiration if they have appropriately fasted or could accurate qualitative and quantitative assessment of gastric contents using ultrasound be used to inform the choice of airway technique during GA for CD. However, with the currently available technology and expertise, it is difficult to confidently use gastric US assessment to decide when the stomach is empty enough to consider using a SAD. Until there are more studies looking at the safety aspects of using a SAD for cesarean section under GA and accurate gastric content assessment, it is still not recommended to use SAD for routine primary airway management in CD.

COVID-19

COVID-19 has prompted professional bodies to publish guidance encouraging the use of RA,[115,116] but recent data suggest that 19% of the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2)-positive women who required a CD received GA.[117] With almost 10% of staff involved in the intubation of suspected or confirmed positive SARS-CoV-2 patients developing symptoms or a positive antigen test afterward,[118] it seems necessary to modify specific steps of our approach in an attempt to minimize exposure of the healthcare professionals while the fundamentals of the anesthetic management remain the same.

Most COVID-19 guidelines recommend face mask preoxygenation with 100% oxygen with a tight-fitting mask via a closed anesthetic circuit and low gas flows to minimize aerosol contamination.[119–122] Although some recommend avoiding the use of low-flow nasal oxygen,[120,122] HFHNO,[119,120,122,123] and noninvasive ventilation (NIV),[119,122] there is no clear evidence of the degree of aerosol generation with these techniques. HFHNO and NIV remain on the UK public health list of aerosol-generating procedures, but studies on high-fidelity human patient simulators suggest that the exhaled air dispersion distance is longer when oxygen is administered at 5 L/min via nasal cannula than with HFHNO or NIV.[124] Moreover, a study in healthy volunteers did not show any significant difference in aerosol production between all 3 techniques.[125] The clinical significance of these observations remains to be defined, but, based on the current recommendations, it seems reasonable to use any of these techniques only when face mask preoxygenation is not adequate.

Intubation, suction of the airway, and face mask ventilation are considered aerosol-generating procedures and many guidelines advocate for the use of video laryngoscopes as the default first-line approach, closed suction systems, and a 2-person "vice-grip" technique to reduce the degree of a leak if FMV is needed. Although SAD devices may theoretically reduce the leak, there is uncertain evidence on SAD and aerosolization. Many reports have highlighted the risks for viral transmission associated with intubation, but the extubation phase may be more perilous.[125] The concentration of aerosol particles was greater during extubation than intubation, with both of them producing significantly fewer particles than a single cough.[126]

Conclusions

RA, with its high safety profile, is still the preferred form of anesthesia in obstetric practice, although GA is sometimes necessary. Advances in obstetric anesthesia have resulted in reduced maternal morbidity and mortality. However, GA and management of failed intubation in the obstetric patient still present unique challenges that differ from the nonpregnant patient. These include a rapid decision-making process that takes into account the safe outcome of the mother and the baby. Preoperative planning and preparation are essential to ensure safe airway management. Optimum positioning and good peri-intubation oxygenation techniques during RSI should help to increase safe apnea time. Video laryngoscopes should be used as the first-line laryngoscope to maximize successful intubation at first attempt. Extubation should be planned, prepared, and performed well, and the standard of care during the recovery period should aim to avoid complications after surgery. Multidisciplinary teaching is vital to enhance safe clinical practice and good teamwork.

Conflicts of interest disclosure

M.C.M. was chair and co-author of the OAA/DAS guidelines for the management of difficult and failed intubation in obstetrics and have been referenced in this article. The remaining authors declare that they have nothing to disclose.

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