

DIFFICULT MASK VENTILATION

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QUESTIONS

Before continuing, try to answer the following questions. The answers can be found at the end of the article, together with an explanation. **Please answer True or False:**

1. **Risk factors for difficult mask ventilation include:**
 - a. A beard
 - b. History of snoring
 - c. BMI > 26kg/m²
 - d. History of alcohol excess
 - e. Female gender
2. **Possible complications of difficult mask ventilation include:**
 - a. Hypoxia
 - b. Brachial plexus injury
 - c. Aspiration
 - d. Eye trauma
 - e. Dislocated jaw
3. **A patient has been given a long acting muscle relaxant, is impossible to mask ventilate and oxygen saturations have fallen to 88%. Appropriate next steps may include:**
 - a. Deepening anaesthesia
 - b. Attempting to wake the patient up
 - c. Attempting laryngoscopy
 - d. Insertion of supraglottic airway device (SAD)
 - e. Performing a surgical airway

Key Points

- Incidence of difficult mask ventilation (MV) is approximately 1.4% and for impossible MV is approximately 0.15%
- It is important to assess patients for difficult MV as well as difficult intubation
- MMMMASK and OBESE are two mnemonics to help remember the risk factors for difficult MV
- Complications are wide-ranging, from trauma to eyes, nose or mouth to hypoxic brain injury and myocardial ischaemia
- When writing your anaesthetic chart it is important to document the ease of MV
- Management of unexpected difficult or impossible MV may benefit from regular airway practice drills or simulation

INTRODUCTION

Mask ventilation (MV) is an integral skill for all anaesthetists. It forms the starting point of the majority of general anaesthetics and more importantly, it is an essential fall-back technique for maintaining oxygenation during a failed or difficult intubation. Despite its importance, less attention is devoted to MV in research papers and textbooks, with a larger focus on difficult or failed intubation. All anaesthetists require the skill to mask ventilate but more importantly they require the knowledge of how to adjust their management options when faced with a difficult or impossible MV scenario. This tutorial will provide an overview of the definition, incidence, predictors and management of difficult MV. There are some clinical situations when MV is not desirable, such as immediately post trans-sphenoidal surgery, but discussion of these is not within the scope of this tutorial.

Definition of difficult mask ventilation

Herein lies a central problem with research on difficult MV - over the years there have been various definitions of what constitutes difficult MV. It is an extremely subjective topic because what constitutes difficulty for an anaesthetic trainee beginning their career may be

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vastly different from an anaesthetic consultant with 25 years' experience. The American Society of Anesthesiologists (ASA) defined difficult MV as a situation in which:

"It is not possible for the anesthesiologist to provide adequate ventilation because of one or more of the following problems: inadequate mask seal, excessive gas leak, or excessive resistance to the ingress or egress of gas."¹

The ASA then goes on to list signs of inadequate ventilation: absent or inadequate chest movement, absent or inadequate breath sounds, auscultatory signs of severe obstruction, cyanosis, gastric air entry or dilatation, decreasing or inadequate oxygen saturation, absent or inadequate exhaled carbon dioxide, absent or inadequate spirometric measures of exhaled gas flow, and haemodynamic changes.

This is a very comprehensive definition but in some ways it remains vague and dependent on the operator's judgment. Other papers have used similar definitions but have specified further criteria. Langeron et al. in 2000 specified inability to maintain saturations above 92%, using the oxygen flush more than twice, requiring 2 operators or a change of operator as indicators for difficult mask ventilation.² Yildiz et al. in 2005 defined the difficulty depending on the airway manoeuvres used.³ Kheterpal et al. in 2006 defined difficult MV as inadequate MV, or MV requiring 2 operators.⁴ In each of these definitions the terms used can be interpreted differently, highlighting the difficulty in finding a universal definition.

Given that achieving a universal definition is difficult, a way of communicating what worked for a patient would obviously be of benefit. As with many conditions in medicine, MV can be considered as a spectrum with one end being easy MV and the other being impossible MV.⁵ A definition to represent the various stages of difficulty to allow easier communication between clinicians was described by Han et al.⁶ It is a grading system 0-4 similar to the Cormack-Lehane grading of views at laryngoscopy, and is shown in Figure 1.

Classification	Description
Grade 0	Ventilation by mask not attempted
Grade 1	Ventilated by mask
Grade 2	Ventilated by mask with oral airway or other adjunct
Grade 3	Difficult MV (inadequate, unstable, or 2 person technique)
Grade 4	Unable to mask ventilate

Figure 1: Table showing MV classification and description scale⁶

Incidence of difficult mask ventilation

There has been a range of incidence reported due to lack of consensus in definition; the quoted range is wide at 0.08% to 15%. The most robust data show the incidence of difficult MV is approximately 1.4%,⁴ and impossible MV is approximately 0.15%.⁷

Factors affecting mask ventilation

Anaesthetic factors

Factors that have been shown to affect MV are the experience of the clinician and the use of equipment. The skill of MV is achieved through training and maintained through regular practice. This helps to address common issues such as patient position, airway manoeuvres and sizing of equipment. The use of incorrectly sized oropharyngeal or nasopharyngeal airways are unlikely to improve MV and may cause trauma and bleeding. Furthermore, MV may be difficult due to an improperly sized mask being used or faults with the anaesthetic machine or breathing circuit.

Some aspects of general anaesthesia itself are thought to play a role. High dose opioids, inadequate depth of anaesthesia and inadequate muscle relaxation may all lead to increased muscle rigidity, reduced chest wall compliance and difficult MV. The chest wall rigidity associated with high dose opioids is not seen in patients with a tracheostomy. This leads to the suggestion that the resistance to MV is actually due to vocal cord closure, which resolves on administration of a muscle relaxant.⁸ These factors have led to debate about the timing of administration of muscle relaxant and whether to check if it is possible to mask ventilate the patient prior to administration. Muscle relaxants can make MV easier, by eliminating rigidity and laryngospasm, or more difficult, by causing loss of tone and upper airway collapse. The 4th National Audit Project by the Royal College of Anaesthetists and Difficult Airway Society (DAS) found that in some cases, light anaesthesia and a reluctance to administer muscle relaxants may have caused patient harm.⁹

The project made the following recommendations:

- "Where facemask or laryngeal mask anaesthesia is complicated by failed ventilation and increasing hypoxia the anaesthetist should consider early administration of further anaesthetic agent and or a muscle relaxant to exclude and treat laryngospasm."
- "No anaesthetist should allow airway obstruction and hypoxia to develop to the stage where an emergency surgical airway is necessary without having administered a muscle relaxant."

Patient factors

Being able to anticipate difficult MV can help anaesthetists formulate an airway management plan that is safe for the patient. A simple and reassuring way of assessing the patient is to check their previous anaesthetic chart for any documented difficulties. This highlights the importance of good record keeping and also demonstrates how a reproducible grading system for mask ventilation can play a vital role in standardising communication between clinicians.

Patient-specific factors can be the main cause for difficult mask ventilation; these are wide-ranging and can be categorised as shown in Figure 2.

Enlarged soft tissues	Abnormal anatomy
<ul style="list-style-type: none"> • Large tongue/epiglottis • Tonsillar hyperplasia • Airway oedema 	<ul style="list-style-type: none"> • Edentulous • Beard • Upper or lower airway tumours • Extrinsic compression of airway • Foreign bodies • Pneumothorax • Bronchopleural fistula • Chest wall deformity • Previous neck irradiation
Physiological reactions	
<ul style="list-style-type: none"> • Laryngospasm • Bronchospasm 	

Figure 2: Patient factors associated with difficult mask ventilation

Other important factors include obesity, increasing age, male gender, Mallampati grading, ability for mandibular protrusion and history of obstructive sleep apnoea. Various BMI values have been used in research papers with one as low as 26kg/m² being a statistically significant predictor of difficult MV.² A high neck circumference (>40cm), which is associated with obesity, also increases the probability of difficult MV.¹⁰ Increasing age is another risk factor and this is likely due to the loss of elasticity in tissues and presence of lung disease. The mandibular protrusion test gives the assessor an indication of the ability to perform an adequate jaw thrust, and is important in patients at risk of upper airway collapse. Furthermore, it is also a good predictor of difficult intubation.

The authors suggest a simple mnemonic to help remember these predictors: **MMMMASK**. Alternatively, Langeron et al. identified 5 criteria that were independent risk factors (**OBESE**) for difficult MV.² Both mnemonics are summarised below.

MMMMASK	OBESE
<p>M Male gender</p> <p>M Mask seal which is affected by beard or being edentulous</p> <p>M Mallampati grade 3 or 4</p> <p>M Mandibular protrusion</p> <p>A Age</p> <p>S Snoring and obstructive sleep apnoea</p> <p>K Kilograms (weight)</p>	<p>O Obese (BMI>26kg/m²)</p> <p>B Bearded</p> <p>E Edentulous</p> <p>S Snoring</p> <p>E Elderly (>55 years)</p>

Figure 3: Two mnemonics helpful for remembering patient factors that are associated with difficult mask ventilation

With respect to impossible mask ventilation, Kheterpal et al. reviewed over 50,000 anaesthetics with an incidence of 0.15% and showed the following independent predictors: neck radiation, male sex, sleep apnoea, Mallampati 3-4, and the presence of a beard.⁷ Neck radiation was the most significant factor in predicting impossible MV and importantly, it is also a significant risk factor for difficult intubation. Careful consideration of airway plans for patients with previous neck radiation is required as surgical access may also be difficult

MANAGEMENT AND COMPLICATIONS

Management

The management of difficult MV can be split into two scenarios: expected and unexpected. With expected difficult MV, simple measures can be taken such as shaving of beards, weight loss and keeping dentures in situ to improve the seal and removing them immediately prior to intubation. Some anaesthetists find it beneficial to slick down beards with jelly to improve the seal, however optimal management is to remove the beard with patient cooperation. As with all cases an airway plan should be formed and discussed with the anaesthetic assistant to allow for preparation of necessary equipment. Optimal preoxygenation is vitally important with the aim of providing an increased apnoeic time to allow more time for airway management before the patient's oxygen saturations decline. Proper positioning of the patient helps to improve the apnoeic time by decreasing dependent atelectasis. In obese patients the ear should be at the same level as the sternal notch and so there may be a need to ramp the patient (figure 4). The ramped position helps to improve both ventilation and laryngoscopy view by aligning the oral, pharyngeal and laryngeal axes.

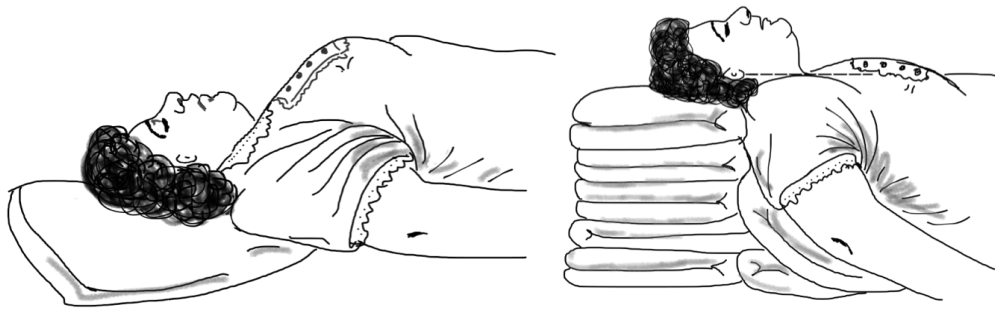


Figure 4: A comparison between supine and ramped position in an obese patient. In a supine position (left), the ear is below the level of the sternal notch. In a ramped position (right), the ear is level with the sternal notch and the face is parallel with the ceiling.

Patel and Nouraei describe an alternate method of maintaining patient oxygenation using Transnasal Humidified Rapid-Insufflation Ventilatory Exchange (THRIVE).¹¹ Continuous high-flow humidified oxygen was delivered transnasally pre- and post-induction of anaesthesia before a definitive airway was secured. This method of apnoeic oxygenation shows promise, however, in their case series they routinely checked that mask ventilation was possible before proceeding. THRIVE only works if the airway remains patent, which is the key to successful MV, so if it is possible to use THRIVE then it should be possible to mask ventilate. In cases where there are signs that suggest difficult MV and a potentially difficult intubation, awake fiberoptic intubation may be the correct choice.

If difficult MV is predicted but an easy intubation anticipated, consideration may be given to rapid sequence induction. The benefit of this approach is quicker onset of neuromuscular blockade to facilitate earlier intubation without the need for MV. The risks associated with this are multiple and should be considered on a case-by-case basis. The main risks include desaturation within the time of onset of muscle relaxation and failure to intubate. In elective cases the back-up plan for these risks would be to insert a SAD to provide ventilation but in emergency non-fasted cases, this risks aspiration. Consideration should be given to awake fiberoptic intubation in these patients. The preoperative visit should include discussion of the options and risks with the patient.

When MV is unexpectedly difficult the management becomes a dynamic process. There is no agreed adult algorithm but the Association of Paediatric Anaesthetists of Great Britain and Ireland along with the DAS have produced an algorithm for difficult MV in children aged 1-8 years.¹² There is a proposed algorithm by El-Orbany and Woehlick detailing the management steps in difficult MV.⁵ Although major anaesthetic groups have yet to adopt this, it represents a sensible approach to the problem.

The first steps in management are: optimising patient position and the use of airway adjuncts such as oropharyngeal and nasopharyngeal airways, the application of continuous positive airway pressure, checking the depth of anaesthesia, muscle relaxation and reducing cricoid pressure. If difficulty remains, i.e. the saturations are dropping or there is a lack of end-tidal carbon dioxide then there should be a call for help to allow a 2-person (or 4-hand) technique and/or change of operator and request for the difficult airway trolley. If this does not improve the situation and the saturations are now <90% the situation should be considered as an impossible MV scenario.

If impossible MV develops, consideration should be given to waking the patient up, however this is not always a feasible option. If a neuromuscular blocking drug has been administered it may be appropriate to attempt intubation at this point or, in the case of rocuronium, to consider reversal with sugammadex. If unable to intubate then 2 attempts at insertion of a SAD would be appropriate if not already attempted. If a neuromuscular blocker has not been given then insertion of a SAD is an alternative. With a SAD in situ, consideration should be given to using it as a conduit to facilitate intubation. If the oxygen saturations are still dropping this is now a Can't Intubate Can't Ventilate (CICV) scenario and requires rescue techniques in the form of either a cannula cricothyroidotomy or surgical cricothyroidotomy. Figure 5 outlines the steps described above.

Chrimes and Fritz describe the Vortex approach as a method to organise the management of this complex and evolving situation.¹³ This looks at achieving oxygenation via a facemask, SAD or endotracheal tube with a maximum of 3 attempts at each. Importantly, they can occur in any order after each has been optimised, and if oxygenation fails with these non-surgical airway techniques, then the next step is an emergency surgical airway. It would be reasonable to suggest that at least one attempt should be made by the most experienced available clinician.

This will have been a stressful situation for the whole team and it will be of benefit to have a team debrief to discuss the events, outcome and raise any concerns for future training. Simulator training is becoming more and more frequent in training in anaesthesia and this type of scenario should be considered.

Accurate documentation of the difficulties (airway adjunct, two-person technique, administration of neuromuscular blocking drugs), together with an explanation of what occurred to the patient, should follow such events.

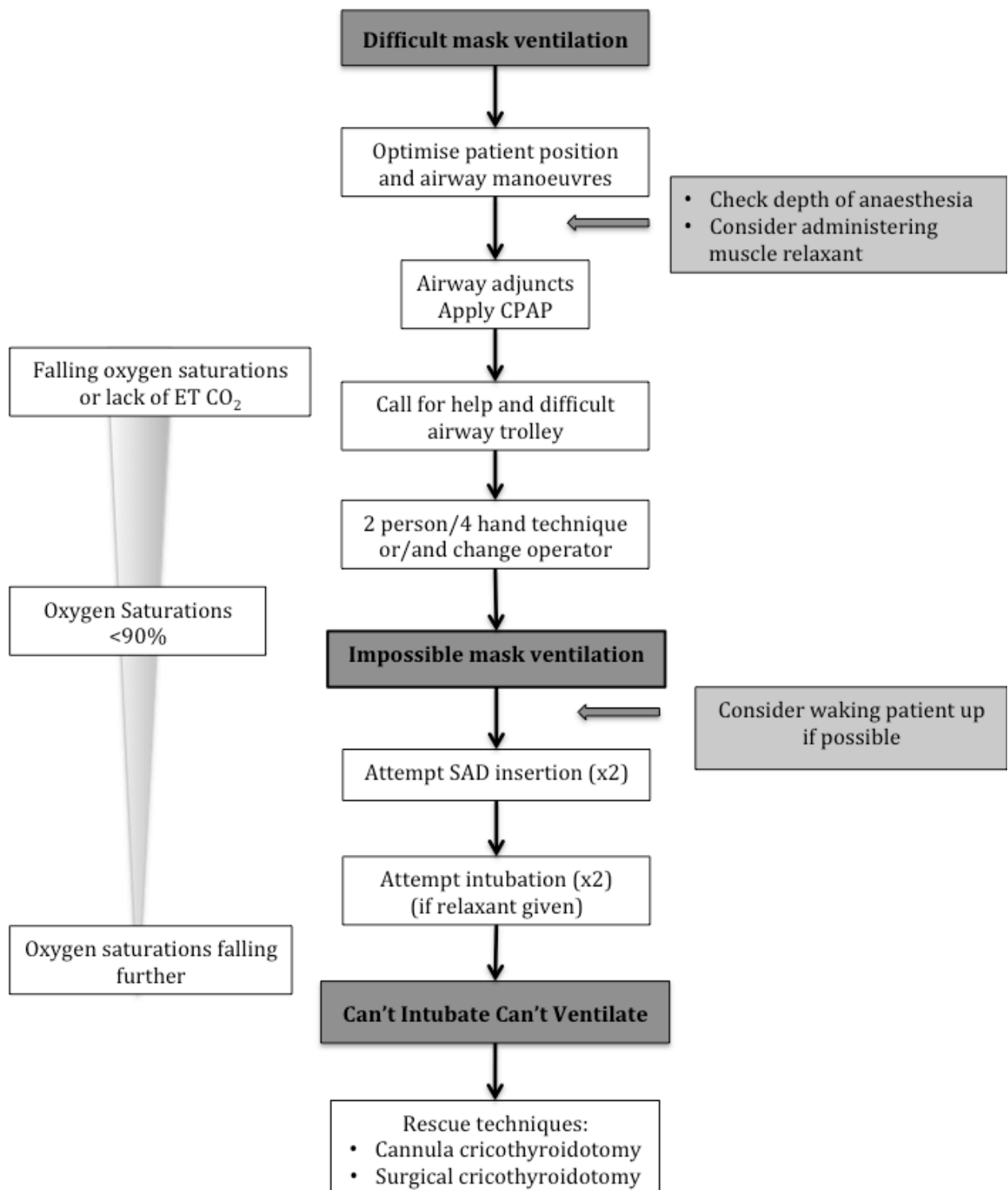


Figure 5: Flowchart for management of unexpected difficult MV

Complications of difficult mask ventilation

Difficult MV can cause numerous complications with the main concern being failure to oxygenate the patient causing death, hypoxic brain injury or myocardial ischaemia. Other complications include injuries to the eyes, nose and mouth. Eye injuries can occur due to direct trauma from the mask or fingers; dry gases leaking from the mask can themselves cause harm. Nasal airway adjuncts can cause false passages and bleeding which may further compromise the airway. Patients may develop pressure injury due to excessive use of force with the mask against the nose. The mouth and oropharynx contain many structures that may be injured during difficult MV; these include teeth, lips, soft palate, uvula and nerves. Lack of lubrication and excessive use of force for insertion of airway adjuncts can increase the risk of this type of trauma.

With increasing difficulty in mask ventilation there is a tendency to increase the inflation pressure via the adjustable pressure-limiting (APL) valve on the anaesthetic machine. This can lead to a vicious cycle: if the airway is not patent, air will be directed into the stomach increasing intra-gastric pressure. This in turn leads to raised diaphragms and a decrease in lung compliance, which leads to more difficult MV. To avoid causing gastric inflation the APL valve should be kept to the minimum requirement and below 20cmH₂O. This is specifically addressed in the paediatric guidelines which suggest the insertion of a nasogastric tube if gastric distension is present.¹² Furthermore, if the airway is patent and being over-ventilated with high pressures, the increased intra-thoracic pressure can compromise venous return and lead to hypotension and decreased coronary perfusion.

Difficult mask ventilation and difficult intubation

This represents the worst-case scenario for most anaesthetists and has led to guidelines being developed for how to manage the CICV scenario. The risk factors for difficult intubation and difficult mask ventilation do have some overlap, for obvious reasons. The incidence of this difficult combination was found by Kheterpal et al. to be approximately 0.4%, with difficulty defined as grade 3 or 4 MV and a grade 3 or 4 view at laryngoscopy.¹⁴ This likely represents an underestimation given that anticipated difficult airways may have received an awake fiberoptic intubation.

Other study by Kheterpal et al. looking at impossible MV found that 19 of the 77 (25%) impossible-to-ventilate patients (out of 50,000 cases) were also difficult to intubate; importantly, 15 of these patients were successfully intubated using various asleep techniques, only 3 were woken up (2 for awake fiberoptic intubation, 1 for awake surgical tracheostomy), and only one required an emergency surgical airway.⁷

ANSWERS TO QUESTIONS

- True.** A beard can cause difficulty in achieving an adequate seal when attempting MV and if concerned, the patient should be advised to shave it off.
 - True.** A history of snoring can indicate upper airway closure when relaxed and may be due to enlarged soft tissues.
 - True.** A BMI of 26kg/m² or more is associated difficult MV.
 - False.** No association with alcohol has been shown.
 - False.** Male gender is associated with increased risk of difficult MV.
- True.** Hypoxia is an obvious complication from difficult MV and may lead to myocardial ischaemia and hypoxic brain injury.
 - False.** There is no association between difficult MV and brachial plexus injury.
 - True.** There is a strong association with high inflation pressures in difficult MV and aspiration risk.
 - True.** This occurs from direct pressure from the mask or from the drying effect of the gases used.
 - False.** No association has been shown.
- False.** Deepening anaesthesia in an adequately paralysed patient will confer no benefit.
 - True.** This depends on the situation and how timely the patient can regain spontaneous breathing and airway patency before critical hypoxia develops. If the time frame permits, then rapid reversal of neuromuscular blockade (i.e. sugammadex), benzodiazepine and opioid may be considered. However, if the likelihood of the patient regaining spontaneous airway patency is low (e.g. no readily available reversal agents), then the priority will be to obtain an airway and oxygenate the patient.
 - True.** An attempt at laryngoscopy would be appropriate, as it would allow oxygenation and ventilation if successful.
 - True.** An attempt at inserting a SAD is also appropriate as it may improve oxygenation and allow you to awaken the patient. This can also be used after a failed attempt at intubation.
 - False.** A surgical airway would be the final step after attempting SAD insertion or intubation.

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