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# Strategies to improve first attempt success at intubation in critically ill patients

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## Abstract

Tracheal intubation in critically ill patients is a high-risk procedure. The risk of complications increases with repeated or prolonged attempts, making expedient first attempt success the goal for airway management in these patients. Patient-related factors often make visualization of the airway and placement of the tracheal tube difficult. Physiologic derangements reduce the patient's tolerance for repeated or prolonged attempts at laryngoscopy and, as a result, hypoxaemia and haemodynamic deterioration are common complications. Operator-related factors such as experience, device selection, and pharmacologic choices affect the odds of a successful intubation on the first attempt. This review will discuss the 'difficult airway' in critically ill patients and highlight recent advances in airway management that have been shown to improve first attempt success and decrease adverse events associated with the intubation of critically ill patients.

**Key words:** airway management; critical care; emergency department; emergency medicine; intensive care; intubation; laryngoscopy; prehospital

## Editor's key points

Airway management in critically ill patients is high risk as a result of anatomic and physiologic characteristics that increase the risk of complications. Complications include hypoxaemia, aspiration of gastric contents, haemodynamic deterioration, hypoxic brain injury, cardiopulmonary arrest and death. One or more complications occur in 22–54% of all intubations performed in critically ill patients, making emergent intubation one of the highest risk procedures a patient may require.[1–5]

The 4th National Audit Project (NAP4) report of the Royal College of Anaesthetists and the Difficult Airway Society identified several deficiencies that increased the risk of adverse outcomes related to emergent airway management.[6] Opportunities identified for improvement include pre-intubation assessment, planning for the initial attempt and identification of back-up plans, and availability and use back-up devices and personnel. Publication of the NAP4 report has invigorated focus on improving the safety of emergency airway management. This review will discuss the 'difficult airway' in critically ill patients and present evidence-based strategies for maximizing first attempt success with airway management in the intensive care unit. The evidence was obtained through relevant search terms in PubMed and articles were evaluated for relevance, applicability and further pertinent references.

## The difficult airway problem and the importance of first attempt success

Critically ill patients often have full stomachs and compromised physiology such that multiple or prolonged attempts are poorly tolerated and result in an increased risk of complications. Griesdale and colleagues[2] reported an overall complication rate of 39% in the intensive care unit, with 13% of all intubations requiring three or more attempts and 10% requiring 10 or more min.

Mort[7] found that when aspiration or hypoxaemia occurs during emergency intubation, patients are 22 times and four times more likely, respectively, to have a cardiac arrest.[7] Patients that had a cardiac arrest during intubation commonly had an oesophageal intubation, which increases the incidence of hypoxaemia and aspiration and increased the risk of death seven-fold. These complications occur more frequently when repeated attempts are required. When more than two attempts were required during emergency intubation, serious complications increased: aspiration of gastric contents (22% *vs* 2%), hypoxaemia (70% *vs* 12%), and cardiac arrest (11% *vs* 1%).[1] More recent data from Sakles and colleagues[8] in the emergency department shows that the risk of adverse events increases with each successive attempt, increasing from 14 to 47% when a second attempt is required. These data suggest that the goal of emergency intubation in the critically ill should be first attempt success.

First attempt success is affected by both patient-related and operator-related factors. Patient-related factors include anatomic features that make visualization of the glottic inlet or the ability to pass a tracheal tube difficult,[9–12] and physiologic factors that limit the duration of the laryngoscopic attempt such as hypoxaemia or haemodynamic instability.[13] Operator-related factors include the experience of the operator,[14–17] device selection,[18–21] and pharmacologic agents used to facilitate the procedure.[22–24] Consequently, any tool that allows the operator to predict the potential difficulty associated with an intubation could be useful for the operator to plan for obviating those potential difficulties.

Difficult intubations are frequently encountered in the emergency department, intensive care unit, and prehospital settings and have been reported to range between 8-13%.[2 3 16 25 26] Conventionally, the 'difficult airway' has been defined as an intubation that requires >2 attempts or 10 min to secure placement of an tracheal tube.[3 16 27] There are several limitations when applying this definition to critically ill patients. First, methods and rules developed to predict the difficult airway have only modest performance.[28–30] Second, utilizing this definition may predict a potentially difficult airway (i.e. >2 attempts), but does not differentiate patients that are at risk of requiring more than one attempt. Many of the patient and operator-related factors described above, and environmental factors such as limited space, poor lighting, and suboptimal bed characteristics that limit the ability to properly position or access the airway, are not included in these prediction models. Lastly, the patient's physiologic derangements may cause difficulty in maintaining oxygenation during the intubation attempt, creating a 'difficult airway' even in the absence of predicted anatomic difficulty.[13 31]

Several methods of pre-intubation assessment aimed at predicting the difficult airway have been developed, all of which focus on the anatomic features that make visualization of the glottic inlet difficult.[11 28 32] These tests have been shown to be difficult to perform in many patients requiring emergency intubation.[33 34] Recently, the MACOCHA score was developed to identify the potentially difficult airway in the intensive care unit. This score considers both patient-related factors pertaining to anatomic difficulty, physiology, and operator-related factors.[32] The components included are: Mallampati score of III or IV, obstructive sleep apnoea, cervical immobility, limited mouth opening, coma, severe hypoxaemia, and non-anaesthetist operators. This seven-item score differentiates difficult from routine intubations with a sensitivity of 73%.[32] Unfortunately, the MACOCHA score does not adequately predict first attempt success, and has not been validated for video laryngoscopy. De Jong and colleagues found that when considering intubations predicted to be difficult by the MACOCHA score, only 4% of intubations performed with the C-MAC video laryngoscope were difficult.[35] Consequently, given the poor reliability of difficult airway *predictors* and difficulty performing pre-intubation assessments properly, attempts to maximize first attempt success should be based on the *characteristics* that make laryngoscopy or placement of a tracheal tube potentially challenging rather than pre-intubation predictors of a 'difficult intubation' that will require >2 attempts or more than 10 min.[36]

## Maximizing first attempt success

### Preoxygenation

Patients undergoing elective surgeries typically have adequate cardiopulmonary optimization before intubation and are usually able to tolerate short periods of apnoea. This degree of optimization may not be possible for critically ill patients, who frequently require intubation unexpectedly with little time for assessment and preparation. In addition, critically ill patients usually have significant physiologic derangements adding another layer of difficulty to airway management. The lack of time, high oxygen requirement, shunt physiology, and lack of patient cooperation all complicate adequate preparation.[3] These factors can increase the risk of complications during intubation. Oxygen desaturation is the most common complication, occurring in 19–70% of intubations.[1–3 37–42] Oxygen desaturation is also likely the most common reason for an aborted first attempt at intubation, both of which increase the risk of further complications. Therefore, optimization of preoxygenation is of particular interest to prolong time to desaturation and thus improve the likelihood of first attempt success.[43]

The process of preoxygenation is used to replace the nitrogen rich ambient air in the alveoli with oxygen, which is then available for uptake during periods of induced apnoea. In healthy patients, this may be achieved by 3–5 min of tidal breathing or eight vital capacity breaths from a tight fitting non-rebreather mask delivering 100% oxygen.[44–47] However, recent data from Groombridge and colleagues[48] showed that in healthy volunteers, a non-rebreather face mask is much less effective in achieving an adequate end tidal O2 than both bag-valve mask and a closed anaesthetic circuit. Hayes-Bradley[49] recently demonstrated that the addition of supplemental oxygen via a nasal cannula in the presence of mask leaks may be helpful in improving end tidal O2. In patients who are critically ill, the effectiveness of and optimal strategy for preoxygenation is not clear. Mort[50] reported that providing 100% oxygen for 4 min increased the partial pressure of arterial oxygen by 6.7 kPa in only 19% of patients, and extending the period of preoxygenation had little impact.[51] In addition to shunt physiology and complicating comorbidities such as obesity, preoxygenation in critically ill patients may be less efficient secondary to the rigid mask typically used, which allows mixing of ambient air causing a decrease in the effective fraction of inspired oxygen. This effect likely worsens with high min ventilation requirements as a greater proportion room air is entrained.

In stable patients undergoing general anaesthesia, a 20-degree elevation of the head has been shown to improve pre-oxygenation and extend safe apnoea time.[52] Non-invasive positive pressure ventilation has also been used to improve pre-oxygenation before intubation in patients with obesity and shunt physiology.[53 54] Baillard and colleagues[53] reported that 3 min of preoxygenation with non-invasive positive pressure ventilation improved preintubation saturation and reduced desaturation to <80% with intubation from 46 to 7% compared with using a nonrebreather mask for 3 min. A supraglottic airway may also be useful for pre-oxygenation before an intubation attempt, in patients requiring higher airway pressures, or that cannot tolerate the non-invasive positive pressure ventilation mask.[55] In patients with severe hypoxaemia and inability to adequately preoxygenate with non-invasive positive pressure ventilation, Delayed Sequence Intubation in which procedural sedation is performed to facilitate mask tolerance and improve preoxygenation before laryngoscopy may be useful.[56] Preoxygenation with positive pressure on the ventilator via a tight fitting facemask, with the addition of supplemental oxygen delivered during the intubation through a nasal cannula may attenuate desaturation in patients with severe hypoxaemia.[57]

High-flow nasal cannulas (HFNC) capable of providing heated, humidified flows of oxygen up to 70 litres per min (lpm) have been compared with standard methods of preoxygenation with mixed results.[58–60] In a pre-post intervention study by Miguel-Montanes and colleagues[58], oxygen delivered at 60 lpm via HFNC for preoxygenation and kept in place during the intubation procedure (apnoeic oxygenation) reduced the incidence of desaturation from 14 to 2% compared with non-rebreather facemask preoxygenation. However, two randomized controlled trials on apnoeic oxygenation have shown no benefit during emergency intubation. Semler[59] and colleagues evaluated 15 lpm through a high-flow nasal cannula compared with usual care and found no difference in the median lowest arterial saturation (92% *vs* 90%) or in the incidence of desaturation to <90% (45% *vs* 47%). Vourc'h and colleagues[60] compared 60 lpm by HFNC for preoxygenation and apnoeic oxygenation to facemask preoxygenation and found no difference in incidence or severity of desaturation. A recent study from Sakles and colleagues[61] in the emergency department has shown an association between apnoeic oxygenation and a higher first attempt success without hypoxemia.

## Maintenance of oxygenation

During apnoeic oxygenation, supplemental oxygen provided to the nasopharynx via a nasal cannula moves to the alveoli by mass diffusion, driven by a gradient caused by ongoing oxygen uptake from the alveoli. This phenomenon has been known for close to a century, and while it does not provide ventilation, apnoeic oxygenation provided through a high-flow nasal cannula during laryngoscopy may decrease desaturation during intubation.[62 63] Apneic oxygenation provided by high flow nasal cannula has also been shown to be useful when awake fiberoptic intubation is required for an anticipated difficult airway.[64] The effectiveness of apnoeic oxygenation in the critically ill patient may be limited because of the presence of disease processes causing a physiologic shunt, which cannot be completely overcome by increased oxygen concentrations. Continuous positive pressure using a nasal non-invasive positive pressure ventilation mask during the intubation may be useful for maintaining alveolar recruitment during intubation, in patients with shunt physiology.[65] More studies are needed to evaluate the role of these modalities to augment oxygenation during intubation, however they represent low cost, low-risk interventions that may improve the safety of emergency intubation.

## Haemodynamic optimization and drug selection

Physiologic difficulties such as hypoxaemia or haemodynamic instability may not inhibit the ability to visualize the vocal cords or pass a tracheal tube, *per se*, but they should be accounted for and may alter the intubation plan. While hypoxaemia makes preoxygenation challenging and limits the duration of safe apnoea, haemodynamic instability is an independent predictor of death after intubation.[66] Post-intubation hypotension is common, reported in nearly half of patients intubated in the intensive care unit,[67] with cardiovascular collapse occurring in 30% of patients.[66–68] In addition to the risk of immediate cardiopulmonary arrest and death after intubation, peri-intubation haemodynamic instability leads to longer intensive care unit stays and increased in-hospital mortality.[66 69–72] Green and colleagues[67] reported an overall incidence of post-intubation hypotension of 46%, which doubled the odds of a composite endpoint of mortality, intensive care unit length of stay >14 days, mechanical ventilation >7 days and renal replacement therapy. When patients required vasopressors within 60 min of intubation, there were even higher odds of in-hospital death (3.84; 95% CI: 1.31–11.57) and a mortality of 38%.[73] Predicting those who will develop post-intubation hypotension has proved difficult. Similar to data from the emergency department,[74] a pre-intubation shock index (heart rate/systolic blood pressure) >0.90 had an odds ratio of 3.17 (95% CI 1.36–7.73) of developing post-intubation hypotension.[75] While pre-intubation shock index may be useful, still one-third of patients with a normal shock index will develop post-intubation hypotension. Based on these data, aggressive resuscitation with volume and vasopressors if necessary should be performed in critically ill patients concurrently with preoxygenation to improve the safety of emergency intubations.

While appropriate fluid resuscitation is the mainstay of preventing post intubation hypotension, the proper selection of pharmacological adjuncts for airway management is also important to prevent cardiovascular collapse. Medications used in airway management should facilitate optimal conditions to place the tracheal tube, while ensuring patient comfort and minimizing adverse haemodynamic effects. Lower doses may be required in critically ill patients based on the haemodynamic profile of the patient, although under-dosing also risks inadequate effects and adverse outcomes such as patient discomfort.

Several induction agents are available for intubation. Haemodynamically neutral induction agents such as etomidate are preferred, or reduced doses of benzodiazepines or propofol, which have properties that lead to myocardial depression and a decrease in systemic vascular resistance.[76–78] While some have raised concerns about transient adrenal insufficiency in patients with sepsis, data are conflicting and convincing evidence of harm is lacking.[79 80] Ketamine is an attractive alternative because of its sympathomimetic effects, which can help maintain blood pressure during intubation. Ketamine has been shown to have no higher rate of complications when compared with etomidate and, unlike other induction agents, it exhibits both amnestic and analgesic properties.[81 82] Ketamine is also valuable in that it allows for the maintenance of spontaneous ventilation by inducing a unique state of dissociative anaesthesia and, as a result, can be useful in facilitating 'awake' intubation techniques. Specific risks associated with ketamine include laryngospasm, myocardial depression and increased airway secretions. Dexmedetomidine, an alpha-2 agonist, may be useful in some patients. Although not an induction agent, the maintenance of spontaneous respiration makes dexmedetomidine an excellent option for awake fiberoptic intubations.

The use of a neuromuscular blocking agents, either in rapid sequence or delayed sequence after the sedative agent, has been shown to improve first attempt success regardless of the choice of induction agent (etomidate *vs* ketamine), neuromuscular blocking agents (succinylcholine *vs* rocuronium) or route of administration (i.v. *vs* intraosseous).[22 56 83–85] Wilcox and colleagues[23] showed that the use of a neuromuscular blocking agent to facilitate intubation in two academic intensive care units was associated with a 7% decrease in hypoxaemia, 5% decrease in complications, and significantly improved intubating conditions, including a 7% increase in first attempt success. Mosier and colleagues[22] reported an odds ratio of first attempt success of 2.37 (95% CI: 1.36–4.88) and no increase in procedurally-related complications, when neuromuscular blocking agents were used in a propensity-matched analysis of 709 consecutive intensive care unit intubations. Neuromuscular blocking agents not only improve grade of view and overall intubating conditions but they also decrease vomiting, especially when combined with a head-up or ramped position.

Pharmacologic adjuncts are available to minimize adverse events with induction although supporting data are limited. Lidocaine, can be given topically to blunt the sympathetic response to laryngoscopy or facilitate the ability to perform an 'awake' intubation in the spontaneously breathing patient. I.V. lidocaine may be used in patients where a raised intracranial pressure (ICP) is a concern to limit spikes in ICP during laryngoscopy. Opiate medications have a similar 'blunting' effect but also have a sedating effect. See Table 1 for a summary of commonly used pharmacologic agents for airway management.

## Device selection

A large variety of devices are available for airway management. Broadly, the devices may be categorized as direct laryngoscopes, indirect laryngoscopes (optical or video laryngoscopes), flexible fiberoptic devices and supraglottic devices. Laryngoscopy has traditionally been performed with a direct laryngoscope, using either a Macintosh or Miller blade. When using a direct laryngoscope, the tissues of the upper airway must be compressed and displaced to provide the operator a view of the glottic inlet. In the last 15 years, video laryngoscopes have become widely available and are currently available in most academic training programs.[86] There are two main categories of video laryngoscopes: standard geometry Macintosh-type curved blade devices, and hyperangulated devices. The hyperangulated devices can be further broken down into those without a tube-guiding channel and those with a channel. The benefit of video laryngoscopy is that the view of the glottic inlet is projected onto a video screen from a camera attached to the undersurface of the blade. This obviates the need to displace the tissues of the upper airway and allows the operator to effectively 'see around the corner'.

Video laryngoscopy has been shown to increase first attempt success in the emergency department, intensive care unit, and pre-hospital setting, including patients with difficult airway predictors and those with a failed first attempt.[18 20 21 87–92] Two randomized controlled-trials were recently published with conflicting results. Griesdale and colleagues[91] reported improved glottic visualization with video laryngoscopy but no difference in first attempt success (40% *vs* 35%), in a pilot study performed in a mixed medical and surgical intensive care unit. A statistically significant increase in first attempt success (74% *vs* 40%) was shown in a second trial, however, using video laryngoscopy in a medical intensive care unit.[90] Both studies excluded patients with anticipated difficult airways, used only one video laryngoscope (GlideScope), and used neuromuscular blocking agents in either all[91] or none[90] of the patients included. A meta-analysis by De Jong and colleagues[18] in 2014 showed first attempt success was twice as likely to occur with the use of a video laryngoscope. The largest comparison of video laryngoscopy to direct laryngoscopy in the intensive care unit to date is a propensity-matched analysis by Hypes and colleagues[19] that demonstrates higher odds of first attempt success (2.81, 95%CI 2.27–3.59) and a lower complication rate when a video laryngoscope was used. Most of the

Table 1 Pharmacologic agents commonly used for airway management. Abbreviations: GABA, Gamma-Aminobutyric Acid; RAS, Reticular Activating System; Ach, Acetylcholine; Na, sodium

| Drug | Dose in mg $kg^{-1}$ | Site/Mechanism of Action | Onset of Action (s) | Duration of Action (min) | Comments |
|---|---|---|---|---|---|
| Sedative Agents | | | | | |
| Etomidate | 0.3 | GABA in RAS | 15–45 | 3–12 | –Haemodynamically neutral |
| Propofol | 1–3 | GABA | 15–45 | 3–5 | –Myocardial depressant-Hypotension |
| Ketamine | 1–2 | GABA, opiate, nicotinic, vascular nitric oxide | <60 | 10–20 | –Direct myocardial depressant but indirect sympathomimetic |
| Thiopental | 3–5 | GABA in RAS | 5–30 | 5–10 | –Negative inotrope-Frequently causes hypotension |
| Midazolam | 0.1–0.3 | GABA in RAS | 30–60 | 15–30 | –Frequently causes hypotension |
| Dexmedetomidine | 0.5–1 mcg $kg^{-1}$ | Alpha-2 agonist | 10–15 min | ~120 | –Blunts laryngeal response-Maintains spontaneous respiration |
| Neuromuscular Blocking Agents | | | | | |
| Succinylcholine | 1–2 | Nicotinic Ach receptors | 30–60 | ~10 | –Only Depolarizing agent |
| Rocuronium | 0.9–1.2 | Ach Receptor Antagonist | 60–90 | ~160 | –Prolonged duration of action |
| Adjuncts | | | | | |
| Lidocaine | 1.5–2.5 | Ionic Na channel | 45–90 | 10–20 | –Local, topical, and i.v. use |
| Opiates | Variable | Mu receptors | 120–180 | 30–60 | –Hypotension because of blunting of sympathetic drive in critically ill patients |
| Benzodiazepines | Variable | GABA | 120–180 | 30–60 | –Hypotension because of blunting of sympathetic drive in critically ill patients, amnesia |

Table 2 Strategies to optimize first attempt success and improve safety of emergent intubations

| Strategy | Method | Comments |
|---|---|---|
| Pre-intubation | | |
| Preoxygenation | 1. >20 degrees head-up position, and<br>2. 3–5 min of 100% oxygen with tight fitting facemask, or HFNC, or<br>3. Non-invasive positive pressure ventilation. | non-invasive positive pressure ventilation is preferred for preoxygenation in patients with shunt physiology. |
| Haemodynamic optimization | 1. Bedside haemodynamic assessment, and<br>2. Fluid resuscitation as necessary, and<br>3. Continuous vasopressor infusion for refractory hypotension despite fluid resuscitation. | 1. Shock index >0.9 has higher odds of developing post-intubation hypotension.<br>2. Bedside ultrasound can provide a rapid, accurate haemodynamic profile. |
| Resource management | 1. Assess potential difficulty, and<br>2. Verbalize 'Plan A,' 'Plan B', etc., and<br>3. Prepare all necessary equipment and backup devices, and<br>4. Position patient, and<br>5. Assign individualized roles for team members, and<br>6. Prepare post-intubation sedation and analgesia. | 1. Potential difficulty includes difficult anatomy and difficult physiology that limit ability to perform laryngoscopy, mask ventilation, supraglottic placement, or surgical airway. |
| Human factors | 1. Presence of two operators with agreement on approach. | |
| During Intubation | | |
| Maintenance of oxygenation | 1. Apnoeic oxygenation may prolong safe apnoea time. | 1. Apnoeic oxygenation efficacy limited with shunt physiology. Nasal CPAP during intubation may be more beneficial in these patients. |
| Device selection | 1. Device selection based on difficulty assessment.<br>2. Video laryngoscopy improves odds of first attempt success. | 1. If fiberoptic intubation is to be performed, combination techniques such as combined fiberoptic device-video laryngoscope or fiberoptic devices-supraglottic device may be useful. |
| Medication selection | 1. Haemodynamically neutral sedative such as etomidate or ketamine, and<br>2. Neuromuscular blocking agent when oral laryngoscopy is being performed. | |
| Programmatic Considerations | | |
| Multidisciplinary approach | 1. Combined training, didactics, simulations, etc. to improve performance of all specialists rather than limit to one specialty. | Difficult airway 'teams' may be useful in some institutions. |
| Training programs | 1. Simulation-based curricula to advance skills in identification and management of the difficult airway. | |
| Human Factors | 1. Education and training on difficult airway algorithms, and<br>2. Use of cognitive aids during intubation to improve recall and performance. | |
| Resource Management | 1. Adequate and readily available equipment is necessary. | 1. Difficult airway carts with all necessary equipment should be available in each ICU. |

literature on video laryngoscopy in critically ill patients involves the C-MAC (Karl Storz, Tuttlingen, Germany) and GlideScope (Verathon, Bothell, WA). These two devices have been shown to be of equal efficacy.[93] When using a hyperangulated video laryngoscope, the use of a rigid stylet is associated with a higher first pass success.[94]

Video laryngoscopes have also been shown to improve first attempt success in logistically challenging situations, such as in patients with in-hospital cardiac arrest, or when performed by novice physicians.[95 96] While direct laryngoscopy is an important skill to maintain for all practitioners that frequently perform intubations, acquiring this skill is difficult, with close to 50 intubations required for an operator to become competent with direct laryngoscopy in uncomplicated patients.[97 98] The learning curve for video laryngoscopy appears much more favorable.[99] An additional benefit of video laryngoscopes is that they play a role in improving human factors associated with airway management. Video laryngoscopes improve training for novices by allowing real-time instruction and provides an avenue for documentation of airway anatomy for future airway management, both of which can improve patient safety and some authors advocate for video laryngoscopy to be the standard of care.[100–102] Based on the available evidence, video laryngoscopy should be considered as the initial device especially in patients with difficult airway characteristics, to maximize the likelihood of first attempt success.

A point of emphasis in the NAP4 report was the lack of availability and use of flexible fiberoptic devices for intubation in patients with challenging airways.[6] Patients with potentially anatomically challenging airways and in whom bag-valve mask ventilation is likely to be difficult or inadequate, may be candidates for an 'awake' intubation using sedation and topical anaesthesia only and a flexible fiberoptic device or video laryngoscope. In operators with limited experience with flexible fiberoptic devices, a combined technique using a flexible fiberoptic device with a laryngoscope can be helpful.[103]

### Human factors: training, algorithms, and bundles

While patient-related factors in critically ill patients, such as altered physiology, present a higher risk of complications during airway management, operator-related factors should be addressed and planned for as well. Intubations in the ICU may be required at any time of day with little time for preparation and thus are often performed by less experienced practitioners. This has sparked controversy over who should perform intubations in the intensive care unit, as interest grows in improving procedural safety.[2 14 16 17 25 104] While anaesthetists may perform more intubations than other specialists, experience, training, comfort and availability for emergent 'out-of-operating theatre' airway management may be variable. Airway management training is an integral part of the training of all specialties that care for critically ill patients and improving training and practice patterns for all specialists perhaps serves better than limiting the skill to one specialty.

Simulation-based training experiences, algorithms, and bundles designed to address this problem have produced varying degrees of success. Jaber and colleagues[105] reported that implementation of an airway management bundle, which included preoxygenation with non-invasive positive pressure ventilation, use of a neuromuscular blocking agent, and fluid loading before intubation decreased the incidence of minor complications by 12% and life-threatening complications by 13%. A quality improvement program for pulmonary and critical care trainees that included a simulation-based training program, crew resource management techniques, a team approach to intubation with assigned roles, and an intubation checklist showed only modest results with a 62% first attempt success rate, 20% of intubations requiring three or more attempts, and an 11% oesophageal intubation rate, although there was no comparison group in this descriptive analysis.[106] Mosier and colleagues[36] recently published a three-year airway management curriculum experience that included an intensive simulation-based program with gradually increasing difficulty focusing on the identification of and approach to the potentially difficult airway. This curriculum improved the odds of first attempt success and decreased complications in the intensive care unit, with an overall first attempt success >80% and nearly 90% when a video laryngoscope was used. Table 2 summarizes the best available evidence to optimize the likelihood of first attempt success and decrease complications for intensive care unit intubations.

The ASA, the Canadian Airway Focus Group, and the Difficult Airway Society have developed excellent guidelines for management of the difficult airway; however, their performance in the emergency department, intensive care unit and pre-hospital is unknown.[27 107–109] Recently, two approaches to airway management in the critically ill have been developed, one as a cognitive aid[110] and one as a strategic algorithm[36] to maintain adequate oxygenation, in patients in the event of a first attempt failure. Further research is needed in this area to guide airway management for the critically ill patient.

## Conclusion

Critically ill patients requiring intubation are challenging because of patient- and operator-related factors that make intubation high-risk for serious complications. First attempt success should be the goal to reduce this risk, which increases with each attempt. Strategies to achieve first attempt success include adequate preoxygenation, apnoeic oxygenation, haemodynamic optimization, and appropriate device and medication selection. Inclusive training programs, algorithms, and cognitive aids should be implemented to improve operator-related factors with airway management. Individualized approaches to airway management for each patient's unique characteristics will optimize the likelihood of first attempt success while maintaining adequate oxygenation and ventilation. Several advances have been made in emergency airway management since the NAP4 report, yet continued research is needed to further address improving identification of high-risk critically ill patients, assessing optimal device and drug selection, and optimizing tools to improve first attempt success and reduce complications.

## Authors' contributions

Study design/planning: B.S.N., J.M., C.D.H., J.C.S., J.M.M.
Study conduct: B.S.N., J.M., C.D.H., J.C.S., J.M.M.
Writing paper: B.S.N., J.M., C.D.H., J.C.S., J.M.M.
Revising paper: all authors

## Declaration of interest

J.C.S. serves on the scientific advisory board for Verathon.

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