

SPECIAL ISSUE

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 colleagues² 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.

Mort⁷ 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 colleagues⁸ 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 colleagues⁴⁸ 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-Bradley⁴⁹ 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. Mort⁵⁰ 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 minute 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 colleagues⁵³ 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 colleagues⁵⁸, 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. Semler⁵⁹ 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 colleagues⁶⁰ 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 colleagues⁶¹ 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} Apnoeic 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 colleagues⁶⁷ 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 colleagues²³ 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 colleagues²² 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 colleagues⁹¹ 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 all⁹¹ or none⁹⁰ of the patients included. A meta-analysis by De Jong and colleagues¹⁸ 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 colleagues¹⁹ 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	<ol style="list-style-type: none"> >20 degrees head-up position, and 3–5 min of 100% oxygen with tight fitting facemask, or HFNC, or Non-invasive positive pressure ventilation. 	non-invasive positive pressure ventilation is preferred for preoxygenation in patients with shunt physiology.
Haemodynamic optimization	<ol style="list-style-type: none"> Bedside haemodynamic assessment, and Fluid resuscitation as necessary, and Continuous vasopressor infusion for refractory hypotension despite fluid resuscitation. 	<ol style="list-style-type: none"> Shock index >0.9 has higher odds of developing post-intubation hypotension. Bedside ultrasound can provide a rapid, accurate haemodynamic profile.
Resource management	<ol style="list-style-type: none"> Assess potential difficulty, and Verbalize 'Plan A,' 'Plan B', etc., and Prepare all necessary equipment and backup devices, and Position patient, and Assign individualized roles for team members, and 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	<ol style="list-style-type: none"> Presence of two operators with agreement on approach. 	
During Intubation		
Maintenance of oxygenation	<ol style="list-style-type: none"> Apnoeic oxygenation may prolong safe apnoea time. 	<ol style="list-style-type: none"> Apnoeic oxygenation efficacy limited with shunt physiology. Nasal CPAP during intubation may be more beneficial in these patients.
Device selection	<ol style="list-style-type: none"> Device selection based on difficulty assessment. Video laryngoscopy improves odds of first attempt success. 	<ol style="list-style-type: none"> 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	<ol style="list-style-type: none"> Haemodynamically neutral sedative such as etomidate or ketamine, and Neuromuscular blocking agent when oral laryngoscopy is being performed. 	
Programmatic Considerations		
Multidisciplinary approach	<ol style="list-style-type: none"> 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	<ol style="list-style-type: none"> Simulation-based curricula to advance skills in identification and management of the difficult airway. 	
Human Factors	<ol style="list-style-type: none"> Education and training on difficult airway algorithms, and Use of cognitive aids during intubation to improve recall and performance. 	
Resource Management	<ol style="list-style-type: none"> Adequate and readily available equipment is necessary. 	<ol style="list-style-type: none"> 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 colleagues¹⁰⁵ 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 colleagues³⁶ 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 aid¹¹⁰ and one as a strategic algorithm³⁶ 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.

References

1. Mort TC. Emergency tracheal intubation: complications associated with repeated laryngoscopic attempts. *Anesth Analg* 2004; **99**: 607–13
2. Griesdale DE, Bosma TL, Kurth T, Isac G, Chittock DR. Complications of endotracheal intubation in the critically ill. *Intensive Care Med* 2008; **34**: 1835–42
3. Jaber S, Amraoui J, Lefrant JY, et al. Clinical practice and risk factors for immediate complications of endotracheal intubation in the intensive care unit: a prospective, multiple-center study. *Crit Care Med* 2006; **34**: 2355–61
4. Simpson GD, Ross MJ, McKeown DW, Ray DC. Tracheal intubation in the critically ill: a multi-centre national study of practice and complications. *Br J Anaesth* 2012; **108**: 792–9
5. Reid C, Chan L, Tweeddale M. The who, where, and what of rapid sequence intubation: prospective observational study of emergency RSI outside the operating theatre. *Emerg Med J* 2004; **21**: 296–301

6. Cook TM, Woodall N, Harper J, Benger J. Major complications of airway management in the UK: results of the Fourth National Audit Project of the Royal College of Anaesthetists and the Difficult Airway Society. Part 2: intensive care and emergency departments. *Br J Anaesth* 2011; **106**: 632–42
7. Mort TC. The incidence and risk factors for cardiac arrest during emergency tracheal intubation: a justification for incorporating the ASA Guidelines in the remote location. *J Clin Anesth* 2004; **16**: 508–16
8. Sakles JC, Chiu S, Mosier J, Walker C, Stolz U. The importance of first pass success when performing orotracheal intubation in the emergency department. *Acad Emerg Med* 2013; **20**: 71–8
9. Hagiwara Y, Watase H, Okamoto H, Goto T, Hasegawa K, Japanese Emergency Medicine Network I-. Prospective validation of the modified LEMON criteria to predict difficult intubation in the ED. *Am J Emerg Med* 2015; **33**: 1492–6
10. Lavery GG, McCloskey BV. The difficult airway in adult critical care. *Crit Care Med* 2008; **36**: 2163–73
11. Mallampati SR, Gatt SP, Gugino LD, et al. A clinical sign to predict difficult tracheal intubation: a prospective study. *Can Anaesth Soc J* 1985; **32**: 429–34
12. Wilson ME, Spiegelhalter D, Robertson JA, Lesser P. Predicting difficult intubation. *Br J Anaesth* 1988; **61**: 211–6
13. Mosier JM, Joshi R, Hypes C, Pacheco G, Valenzuela T, Sakles JC. The physiologically difficult airway. *West J Emerg Med* 2015; **16**: 1109–17
14. Doerschug KC. Counterpoint: should an anesthesiologist be the specialist of choice in managing the difficult airway in the ICU? Not necessarily. *Chest* 2012; **142**: 1375–7
15. Schmidt UH, Kumwilaisak K, Bittner E, George E, Hess D. Effects of supervision by attending anesthesiologists on complications of emergency tracheal intubation. *Anesthesiology* 2008; **109**: 973–7
16. Schwartz DE, Matthay MA, Cohen NH. Death and other complications of emergency airway management in critically ill adults. A prospective investigation of 297 tracheal intubations. *Anesthesiology* 1995; **82**: 367–76
17. Walz JM. Point: should an anesthesiologist be the specialist of choice in managing the difficult airway in the ICU? Yes. *Chest* 2012; **142**: 1372–4
18. De Jong A, Molinari N, Conseil M, et al. Video laryngoscopy versus direct laryngoscopy for orotracheal intubation in the intensive care unit: a systematic review and meta-analysis. *Intensive Care Med* 2014; **40**: 629–39
19. Hypes CD, Stolz U, Sakles JC, et al. Video laryngoscopy improves odds of first attempt success at intubation in the ICU: a Propensity-matched analysis. *Ann Am Thorac Soc* 2016; **13**: 382–90
20. Mosier JM, Stolz U, Chiu S, Sakles JC. Difficult airway management in the emergency department: GlideScope video-laryngoscopy compared to direct laryngoscopy. *J Emerg Med* 2012; **42**: 629–34
21. Sakles JC, Mosier JM, Chiu S, Keim SM. Tracheal intubation in the emergency department: a comparison of GlideScope(R) video laryngoscopy to direct laryngoscopy in 822 intubations. *J Emerg Med* 2012; **42**: 400–5
22. Mosier JM, Sakles JC, Stolz U, et al. Neuromuscular blockade improves first-attempt success for intubation in the intensive care unit. A propensity matched analysis. *Ann Am Thorac Soc* 2015; **12**: 734–41
23. Wilcox SR, Bittner EA, Elmer J, et al. Neuromuscular blocking agent administration for emergent tracheal intubation is associated with decreased prevalence of procedure-related complications. *Crit Care Med* 2012; **40**: 1808–13
24. Sakles JC, Laurin EG, Rantapaa AA, Panacek EA. Airway management in the emergency department: a one-year study of 610 tracheal intubations. *Ann Emerg Med* 1998; **31**: 325–32
25. Jabre P, Avenel A, Combes X, et al. Morbidity related to emergency endotracheal intubation—a substudy of the KETamine SEDation trial. *Resuscitation* 2011; **82**: 517–22
26. Breckwoldt J, Klemstein S, Brunne B, Schnitzer L, Mochmann HC, Arntz HR. Difficult prehospital endotracheal intubation - predisposing factors in a physician based EMS. *Resuscitation* 2011; **82**: 1519–24
27. Apfelbaum JL, Hagberg CA, Caplan RA, et al. Practice guidelines for management of the difficult airway: an updated report by the American Society of Anesthesiologists Task Force on Management of the Difficult Airway. *Anesthesiology* 2013; **118**: 251–70
28. Reed MJ, Dunn MJ, McKeown DW. Can an airway assessment score predict difficulty at intubation in the emergency department? *Emerg Med J* 2005; **22**: 99–102
29. Shiga T. Predicting difficult intubation in apparently normal patients: a meta-analysis of bedside screening test performance. *Anesthesiology*. 2005; 429–37
30. Norskov AK, Rosenstock CV, Wetterslev J, Astrup G, Afshari A, Lundstrom LH. Diagnostic accuracy of anaesthesiologists' prediction of difficult airway management in daily clinical practice: a cohort study of 188 064 patients registered in the Danish Anaesthesia Database. *Anaesthesia* 2015; **70**: 272–81
31. Weingart SD, Levitan RM. Preoxygenation and prevention of desaturation during emergency airway management. *Ann Emerg Med* 2012; **59**: 165–75 e1
32. De Jong A, Molinari N, Terzi N, et al. Early identification of patients at risk for difficult intubation in the intensive care unit: development and validation of the MACOCHA score in a multicenter cohort study. *Am J Respir Crit Care Med* 2013; **187**: 832–9
33. Bair AE, Caravelli R, Tyler K, Laurin EG. Feasibility of the pre-operative Mallampati airway assessment in emergency department patients. *J Emerg Med* 2010; **38**: 677–80
34. Levitan RM, Everett WW, Ochroch EA. Limitations of difficult airway prediction in patients intubated in the emergency department. *Ann Emerg Med* 2004; **44**: 307–13
35. De Jong A, Clavieras N, Conseil M, et al. Implementation of a combo videolaryngoscope for intubation in critically ill patients: a before-after comparative study. *Intensive Care Med* 2013; **39**: 2144–52
36. Mosier JM, Malo J, Sakles JC, et al. The impact of a comprehensive airway management training program for pulmonary and critical care medicine fellows. A three-year experience. *Ann Am Thorac Soc* 2015; **12**: 539–48
37. Bodily JB, Webb HR, Weiss SJ, Braude DA. Incidence and duration of continuously measured oxygen desaturation during emergency department intubation. *Ann Emerg Med* 2016; **67**: 389–95
38. Kerrey BT, Mittiga MR, Rinderknecht AS, et al. Reducing the incidence of oxyhaemoglobin desaturation during rapid sequence intubation in a paediatric emergency department. *Br Med J Qual Saf* 2015; **24**: 709–17
39. Kerrey BT, Rinderknecht AS, Geis GL, Nigrovic LE, Mittiga MR. Rapid sequence intubation for pediatric emergency patients: higher frequency of failed attempts and adverse effects found by video review. *Ann Emerg Med* 2012; **60**: 251–9
40. Prekker ME, Delgado F, Shin J, et al. Pediatric intubation by paramedics in a large emergency medical services system:

- process, challenges, and outcomes. *Ann Emerg Med* 2016; **67**: 20–9 e4
41. Sunde GA, Heltne JK, Lockey D, et al. Airway management by physician-staffed Helicopter Emergency Medical Services - a prospective, multicentre, observational study of 2,327 patients. *Scand J Trauma Resusc Emerg Med* 2015; **23**: 57
 42. Dunford JV, Davis DP, Ochs M, Doney M, Hoyt DB. Incidence of transient hypoxia and pulse rate reactivity during paramedic rapid sequence intubation. *Ann Emerg Med* 2003; **42**: 721–8
 43. Davis DP, Lemieux J, Serra J, Koenig W, Aguilar SA. Preoxygenation reduces desaturation events and improves intubation success. *Air Med J* 2015; **34**: 82–5
 44. Baraka A, Haroun-Bizri S, Khoury S, Chehab IR. Single vital capacity breath for preoxygenation. *Can J Anaesth* 2000; **47**: 1144–6
 45. Baraka AS, Taha SK, Aouad MT, El-Khatib MF, Kawkabani NI. Preoxygenation: comparison of maximal breathing and tidal volume breathing techniques. *Anesthesiology* 1999; **91**: 612–6
 46. Baraka AS, Taha SK, El-Khatib MF, Massouh FM, Jabbour DG, Alameddine MM. Oxygenation using tidal volume breathing after maximal exhalation. *Anesth Analg* 2003; **97**: 1533–5
 47. Hamilton WK, Eastwood DW. A study of denitrogenation with some inhalation anesthetic systems. *Anesthesiology* 1955; **16**: 861–7
 48. Groombridge C, Chin CW, Hanrahan B, Holdgate A. Assessment of common preoxygenation strategies outside of the operating room environment. *Acad Emerg Med* 2016; **23**: 342–6
 49. Hayes-Bradley C, Lewis A, Burns B, Miller M. Efficacy of nasal cannula oxygen as a preoxygenation adjunct in emergency airway management. *Ann Emerg Med Advance Access published on Dec 31, 2015*, doi:10.1016/j.annemergmed.2015.11.012
 50. Mort TC. Preoxygenation in critically ill patients requiring emergency tracheal intubation. *Crit Care Med* 2005; **33**: 2672–5
 51. Mort TC, Waberski BH, Clive J. Extending the preoxygenation period from 4 to 8 mins in critically ill patients undergoing emergency intubation. *Crit Care Med* 2009; **37**: 68–71
 52. Lane S, Saunders D, Schofield A, Padmanabhan R, Hildreth A, Laws D. A prospective, randomised controlled trial comparing the efficacy of pre-oxygenation in the 20 degrees head-up vs supine position. *Anaesthesia* 2005; **60**: 1064–7
 53. Baillard C, Fosse JP, Sebbane M, et al. Noninvasive ventilation improves preoxygenation before intubation of hypoxic patients. *Am J Respir Crit Care Med* 2006; **174**: 171–7
 54. El-Khatib MF, Kanazi G, Baraka AS. Noninvasive bilevel positive airway pressure for preoxygenation of the critically ill morbidly obese patient. *Can J Anaesth* 2007; **54**: 744–7
 55. Braude D, Richards M. Rapid sequence airway (RSA)—a novel approach to prehospital airway management. *Prehosp Emerg Care* 2007; **11**: 250–2
 56. Weingart SD, Trueger NS, Wong N, Scofi J, Singh N, Rudolph SS. Delayed sequence intubation: a prospective observational study. *Ann Emerg Med* 2015; **65**: 349–55
 57. Grant S, Khan F, Keijzers G, Shirran M, Marneros L. Ventilator-assisted preoxygenation: Protocol for combining non-invasive ventilation and apnoeic oxygenation using a portable ventilator. *Emerg Med Australas* 2016; **28**: 67–72
 58. Miguel-Montanes R, Hajage D, Messika J, et al. Use of high-flow nasal cannula oxygen therapy to prevent desaturation during tracheal intubation of intensive care patients with mild-to-moderate hypoxemia*. *Crit Care Med* 2015; **43**: 574–83
 59. Semler MW, Janz DR, Lentz RJ, et al. Randomized trial of apneic oxygenation during endotracheal intubation of the critically ill. *Am J Respir Crit Care Med* 2016; **193**: 273–80
 60. Vourc'h M, Asfar P, Volteau C, et al. High-flow nasal cannula oxygen during endotracheal intubation in hypoxemic patients: a randomized controlled clinical trial. *Intensive Care Med* 2015; **41**: 1538–48
 61. Sakles JC, Mosier JM, Patanwala AE, Arcaris B, Dicken J. First pass success without hypoxemia is increased with the use of apneic oxygenation during RSI in the emergency department. *Acad Emerg Med Advance Access published on Feb 2, 2016*, doi:10.1111/acem.12931
 62. Ramachandran SK, Cosnowski A, Shanks A, Turner CR. Apneic oxygenation during prolonged laryngoscopy in obese patients: a randomized, controlled trial of nasal oxygen administration. *J Clin Anesth* 2010; **22**: 164–8
 63. Wimalasena Y, Burns B, Reid C, Ware S, Habig K. Apneic oxygenation was associated with decreased desaturation rates during rapid sequence intubation by an Australian helicopter emergency medicine service. *Ann Emerg Med* 2015; **65**: 371–6
 64. Badiger S, John M, Fearnley RA, Ahmad I. Optimizing oxygenation and intubation conditions during awake fibre-optic intubation using a high-flow nasal oxygen-delivery system. *Br J Anaesth* 2015; **115**: 629–32
 65. Barjaktarevic I, Berlin D. Bronchoscopic intubation during continuous nasal positive pressure ventilation in the treatment of hypoxemic respiratory failure. *J Intensive Care Med* 2015; **30**: 161–6
 66. Heffner AC, Swords D, Kline JA, Jones AE. The frequency and significance of postintubation hypotension during emergency airway management. *J Crit Care* 2012; **27**: 417 e9–13
 67. Green RS, Turgeon AF, McIntyre LA, et al. Postintubation hypotension in intensive care unit patients: A multicenter cohort study. *J Crit Care* 2015; **30**: 1055–60
 68. Perbet S, De Jong A, Delmas J, et al. Incidence of and risk factors for severe cardiovascular collapse after endotracheal intubation in the ICU: a multicenter observational study. *Crit Care* 2015; **19**: 257
 69. Green RS, Edwards J, Sabri E, Fergusson D. Evaluation of the incidence, risk factors, and impact on patient outcomes of postintubation hemodynamic instability. *CJEM* 2012; **14**: 74–82
 70. Griesdale DE, Henderson WR, Green RS. Airway management in critically ill patients. *Lung* 2011; **189**: 181–92
 71. Heffner AC, Swords DS, Neale MN, Jones AE. Incidence and factors associated with cardiac arrest complicating emergency airway management. *Resuscitation* 2013; **84**: 1500–4
 72. Kim WY, Kwak MK, Ko BS, et al. Factors associated with the occurrence of cardiac arrest after emergency tracheal intubation in the emergency department. *PLoS One* 2014; **9**: e112779
 73. Smischney NJ, Demirci O, Richter BD, et al. Vasopressor use as a surrogate for post-intubation hemodynamic instability is associated with in-hospital and 90-day mortality: a retrospective cohort study. *BMC Res Notes* 2015; **8**: 445
 74. Heffner AC, Swords DS, Nussbaum ML, Kline JA, Jones AE. Predictors of the complication of postintubation hypotension during emergency airway management. *J Crit Care* 2012; **27**: 587–93
 75. Trivedi S, Demirci O, Arteaga G, Kashyap R, Smischney NJ. Evaluation of preintubation shock index and modified shock index as predictors of postintubation hypotension and other short-term outcomes. *J Crit Care* 2015; **30**: 861.e1–7
 76. Shah SB, Chowdhury I, Bhargava AK, Sabbharwal B. Comparison of hemodynamic effects of intravenous etomidate versus propofol during induction and intubation using entropy guided hypnosis levels. *J Anaesthesiol Clin Pharmacol* 2015; **31**: 180–5

77. Kaushal RP, Vatal A, Pathak R. Effect of etomidate and propofol induction on hemodynamic and endocrine response in patients undergoing coronary artery bypass grafting/mitral valve and aortic valve replacement surgery on cardiopulmonary bypass. *Ann Card Anaesth* 2015; **18**: 172–8
78. Reich DL, Hossain S, Krol M, et al. Predictors of hypotension after induction of general anesthesia. *Anesth Analg* 2005; **101**: 622–8
79. Chan CM, Mitchell AL, Shorr AF. Etomidate is associated with mortality and adrenal insufficiency in sepsis: a meta-analysis*. *Crit Care Med* 2012; **40**: 2945–53
80. Gu WJ, Wang F, Tang L, Liu JC. Single-dose etomidate does not increase mortality in patients with sepsis: a systematic review and meta-analysis of randomized controlled trials and observational studies. *Chest* 2015; **147**: 335–46
81. Patanwala AE, McKinney CB, Erstad BL, Sakles JC. Retrospective analysis of etomidate versus ketamine for first-pass intubation success in an academic emergency department. *Acad Emerg Med* 2014; **21**: 87–91
82. Sih K, Campbell SG, Tallon JM, Magee K, Zed PJ. Ketamine in adult emergency medicine: controversies and recent advances. *Ann Pharmacother* 2011; **45**: 1525–34
83. Marsch SC, Steiner L, Bucher E, et al. Succinylcholine versus rocuronium for rapid sequence intubation in intensive care: a prospective, randomized controlled trial. *Crit Care* 2011; **15**: R199
84. Barnard EB, Moy RJ, Kehoe AD, Bebartta VS, Smith JE. Rapid sequence induction of anaesthesia via the intraosseous route: a prospective observational study. *Emerg Med J* 2015; **32**: 449–52
85. Lyon RM, Perkins ZB, Chatterjee D, et al. Significant modification of traditional rapid sequence induction improves safety and effectiveness of pre-hospital trauma anaesthesia. *Crit Care* 2015; **19**: 134
86. Silverberg MJ, Kory P. Survey of video laryngoscopy use by U. S. critical care fellowship training programs. *Ann Am Thorac Soc* 2014; **11**: 1225–9
87. Michailidou M, O'Keeffe T, Mosier JM, et al. A comparison of video laryngoscopy to direct laryngoscopy for the emergency intubation of trauma patients. *World J Surg* 2015; **39**: 782–8
88. Sakles JC, Mosier JM, Patanwala AE, Dicken JM, Kalin L, Javedani PP. The C-MAC(R) video laryngoscope is superior to the direct laryngoscope for the rescue of failed first-attempt intubations in the emergency department. *J Emerg Med* 2015; **48**: 280–6
89. Sakles JC, Patanwala AE, Mosier JM, Dicken JM. Comparison of video laryngoscopy to direct laryngoscopy for intubation of patients with difficult airway characteristics in the emergency department. *Intern Emerg Med* 2014; **9**: 93–8
90. Silverberg MJ, Li N, Acquah SO, Kory PD. Comparison of video laryngoscopy versus direct laryngoscopy during urgent endotracheal intubation: a randomized controlled trial. *Crit Care Med* 2015; **43**: 636–41
91. Griesdale DE, Chau A, Isac G, et al. Video-laryngoscopy versus direct laryngoscopy in critically ill patients: a pilot randomized trial. *Can J Anaesth* 2012; **59**: 1032–9
92. Jarvis JL, McClure SF, Johns D. EMS Intubation Improves with King Vision Video Laryngoscopy. *Prehosp Emerg Care* 2015; **19**: 482–9
93. Mosier J, Chiu S, Patanwala AE, Sakles JC. A comparison of the GlideScope video laryngoscope to the C-MAC video laryngoscope for intubation in the emergency department. *Ann Emerg Med* 2013; **61**: 414–20. e1
94. Sakles JC, Kalin L. The effect of stylet choice on the success rate of intubation using the GlideScope video laryngoscope in the emergency department. *Acad Emerg Med* 2012; **19**: 235–8
95. Park SO, Kim JW, Na JH, et al. Video laryngoscopy improves the first-attempt success in endotracheal intubation during cardiopulmonary resuscitation among novice physicians. *Resuscitation* 2015; **89**: 188–94
96. Lee DH, Han M, An JY, et al. Video laryngoscopy versus direct laryngoscopy for tracheal intubation during in-hospital cardiopulmonary resuscitation. *Resuscitation* 2015; **89**: 195–9
97. Mulcaster JT, Mills J, Hung OR, et al. Laryngoscopic intubation: learning and performance. *Anesthesiology* 2003; **98**: 23–7
98. Buis ML, Maissan IM, Hoeks SE, Klimek M, Stalker RJ. Defining the learning curve for endotracheal intubation using direct laryngoscopy: a systematic review. *Resuscitation* 2016; **99**: 63–71
99. Sakles JC, Mosier J, Patanwala AE, Dicken J. Learning curves for direct laryngoscopy and GlideScope(R) video laryngoscopy in an emergency medicine residency. *West J Emerg Med* 2014; **15**: 930–7
100. Aseri S, Ahmad H, Vallance H. Video laryngoscopy improves endotracheal intubation training for novices. *Br J Anaesth* 2015; **115**: 133
101. Kelly FE, Cook TM, Boniface N, Hughes J, Seller C, Simpson T. Videolaryngoscopes confer benefits in human factors in addition to technical skills. *Br J Anaesth* 2015; **115**: 132–3
102. Zaouter C, Calderon J, Hemmerling TM. Videolaryngoscopy as a new standard of care. *Br J Anaesth* 2015; **114**: 181–3
103. Lenhardt R, Burkhart MT, Brock GN, Kanchi-Kandadai S, Sharma R, Akka O. Is video laryngoscope-assisted flexible tracheoscope intubation feasible for patients with predicted difficult airway? A prospective, randomized clinical trial. *Anesth Analg* 2014; **118**: 1259–65
104. Benedetto WJ, Hess DR, Gettings E, et al. Urgent tracheal intubation in general hospital units: an observational study. *J Clin Anesth* 2007; **19**: 20–4
105. Jaber S, Jung B, Corne P, et al. An intervention to decrease complications related to endotracheal intubation in the intensive care unit: a prospective, multiple-center study. *Intensive Care Med* 2010; **36**: 248–55
106. Mayo PH, Hegde A, Eisen LA, Kory P, Doelken P. A program to improve the quality of emergency endotracheal intubation. *J Intensive Care Med* 2011; **26**: 50–6
107. Frerk C, Mitchell VS, McNarry AF, et al. Difficult Airway Society 2015 guidelines for management of unanticipated difficult intubation in adults. *Br J Anaesth* 2015; **115**: 827–48
108. Law JA, Broemling N, Cooper RM, et al. The difficult airway with recommendations for management—part 1—difficult tracheal intubation encountered in an unconscious/induced patient. *Can J Anaesth* 2013; **60**: 1089–118
109. Law JA, Broemling N, Cooper RM, et al. The difficult airway with recommendations for management—part 2—the anticipated difficult airway. *Can J Anaesth* 2013; **60**: 1119–38
110. Chrimes NC. The Vortex: striving for simplicity, context independence and teamwork in an airway cognitive tool. *Br J Anaesth* 2015; **115**: 148–9