ANESTHESIOLOGY

Preparation for and Management of "Failed" Laryngoscopy and/or Intubation

Richard M. Cooper, M.Sc., M.D.

ANESTHESIOLOGY 2019; 130:833–49

ABSTRACT

An airway manager's primary objective is to provide a path to oxygenation. This can be achieved by means of a facemask, a supraglottic airway, or a tracheal tube. If one method fails, an alternative approach may avert hypoxia. We cannot always predict the difficulties with each of the methods, but these difficulties may be overcome by an alternative technique. Each unsuccessful attempt to maintain oxygenation is time lost and may incrementally increase the risk of hypoxia, trauma, and airway obstruction necessitating a surgical airway. We should strive to optimize each effort. Differentiation between failed laryngoscopy and failed intubation is important because the solutions differ. Failed facemask ventilation may be easily managed with an supraglottic airway or alternatively tracheal intubation. When alveolar ventilation cannot be achieved by facemask, supraglottic airway, or tracheal intubation, every anesthesiologist should be prepared to perform an emergency surgical airway to avert disaster.

(Anesthesiology 2019; 130:833–49)

As anesthesiologists, we take great pride in our airway management skills. We are frequently called upon when other first responders are unable to ventilate or intubate a patient's trachea. However, adverse outcomes continue to occur that can be devastating to patients, their families, and those involved in their care. We know from the American Society of Anesthesiologists (ASA) Closed Claims database that adverse events as a result of airway management account for a large proportion of claims resulting in brain injury and death.[1] Many of these cases resulted from substandard care. Although Closed Claims may provide a somewhat distorted lens, similar themes were echoed by the 4th National Audit Project in the United Kingdom, where serious adverse outcomes including brain injury, death, an emergency surgical airway, or unintended intensive care unit admission resulted from airway management.[2] The 4th National Audit Project provided a window on virtually all of the 2.9 million airway interventions in publicly funded hospitals throughout the United Kingdom over 1 yr. The majority of the adverse outcomes resulted from poor care. This study offers a recent benchmark for the safety of airway management.

Both the ASA Closed Claims project and the 4th National Audit Project studies look at very serious adverse events, but as Cook recently noted, "defining failure is part of the problem."[3] Most anesthesiologists frequently encounter airway difficulties or some measure of failure, from the very minor to the catastrophic. This may involve our inability to obtain a good seal with a facemask, a leak with a supraglottic airway, gastric distension from facemask ventilation, regurgitation, epistaxis placing a nasal tube, more than one laryngoscopic attempt, or attempting intubation despite a Cormack–Lehane view grade of III or higher.[4] Each of these "failures" is associated with an increased risk of other, potentially more serious complications. Avoidance of these minor and potentially serious complications requires recognition that often they can be avoided by meticulous care. Clearly the avoidance of brain damage and death are imperative but are insufficient. We can and must set a higher expectation for quality care.

Central to airway management is ventilation and oxygenation by a facemask, a supraglottic airway, or a tracheal tube. Generally, tracheal intubation is achieved by laryngoscopy. Each of these interventions may pose challenges and be accompanied by physiologic consequences that must be managed.

The ASA Task Force on Management of the Difficult Airway has provided definitions of these difficulties.[5] They include difficulty with ventilation by facemask or a supraglottic airway, difficulty with laryngoscopy, and/or intubation and difficulty securing an emergency surgical airway. Sometimes these challenges overlap, but often an alternative approach will succeed after failure of previous strategies. Thus, the avoidance of patient harm makes it is essential that the airway manager remain mindful and willing to change course when difficulties are encountered.

Commonly used definitions of a "difficult airway" need to be examined more critically. For example, "difficult laryngoscopy" has been defined by the ASA Task Force on Airway Management as the inability of a trained anesthesiologist to "visualize any portion of the vocal cords after *multiple attempts* at conventional laryngoscopy."[5] In 1994,

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<zdoi;10.1097/ALN.0000000000002555>

Rose and Cohen[6] reported that when difficulties were encountered with *direct* laryngoscopy, anesthesiologists at their hospital most commonly repeated attempts with *direct* laryngoscopy. (However, a multicenter database review conducted between 2004 and 2013 suggests that at least at the seven participating American academic centers, anesthesiologists were not persisting with unsuccessful techniques.[7] It is unclear the extent to which we can generalize this encouraging observation.) Because alternative techniques are more widely used for initial and rescue efforts, one can no longer make assumptions about the device used. When describing laryngoscopy, it is essential to specify the technique that was employed (*e.g.*, Macintosh #3 laryngoscopy → Cormack–Lehane III view; C-MAC D-blade [Karl Storz, Germany] #3 → Cormack–Lehane I). (The C-MAC "D-blade" is an example of a hyperangulated blade. Like the GlideScope Lo-Pro [Verathon, USA], it is essentially a modified Macintosh blade with greater convexity of its lingual surface, providing a more anteriorly oriented indirect view.) However, repeated attempts at laryngoscopy may compromise our ability to ventilate by facemask or a supraglottic airway, as well as efforts to achieve intubation. This author takes issue with the lack of specificity of the ASA Airway Management Task Force definition regarding the device used, the number of attempts, and the definition of failure. Similarly, "difficult tracheal intubation" is defined by the ASA Task Force as the need for *multiple attempts* to pass a tracheal tube.[5] This author contends that when laryngoscopy fails to reveal the larynx but blind tracheal intubation is successful, this is a "near miss" rather than an easy airway. Esophageal intubation might just as easily have resulted with a potential delay in recognition, gastric distension, regurgitation, aspiration, and further hypoxemia. Each attempt carries incremental risk,[8–13] and that risk likely increases as the patient's physiologic reserve declines.[12] Most other societies and airway guidelines advocate for a specific though admittedly arbitrary limit to the number of acceptable attempts.[10,14–17] A specified limit promotes critical thinking and discourages persistence with nonproductive strategies. Vague terms such as "multiple," "awkward,"[6] "difficult," "slight difficulty,"[18] and "fairly severe difficulty"[18] are not informative.

Most airway guidelines state or imply that a patient known or presumed to be a difficult laryngoscopy or intubation should be managed in a manner that maintains spontaneous ventilation. However, given that the definition of a "difficult laryngoscopy" is problematic and difficulty with one device does not necessarily indicate difficulties with other techniques. Conventional bedside predictors have been validated for *direct* laryngoscopy and may not apply if another technique is used.[19–21] Furthermore, these predictors are in fact not very predictive, even for direct laryngoscopy. In other words, a known or presumed difficult or failed direct laryngoscopy may not in fact be difficult if an alternative technique is employed by an experienced user. If a difficult laryngoscopy is anticipated, the airway manager must assess whether prior experience is sufficient to permit confidence that spontaneous ventilation can be sacrificed. The clinician must assess which technique or device has the greatest probability of safely achieving success given the prevailing circumstances. Finally, if the clinician is wrong, there must be a robust backup plan. Absent reassuring answers to those concerns, it is probably prudent to preserve spontaneous ventilation.

This narrative review will endeavor to examine our understanding and prevention of, preparation for, and response to a failed laryngoscopy and/or intubation. It is based largely on the evidence used to formulate the various national airway management guidelines and subsequent reports. However, much of that literature offers limited high-quality evidence, and accordingly many recommendations are based upon expert opinion. Where this author takes a position that differs from the prevailing guidelines, such opinions will be identified as such.

Definitions

Failed Laryngoscopy and Intubation

When Cormack and Lehane proposed their classification of the laryngeal views, direct laryngoscopy was the only technique used. They reasonably proposed that the quality of the view correlated with the ease of intubation,[18] and the laryngeal view came to be regarded as a practical surrogate for difficulty.[22] However, with indirect techniques such as video laryngoscopy, intubation sometimes fails despite good laryngeal exposure.[23] This author believes that this does not devalue the Cormack–Lehane view as a descriptor of the laryngeal view when using video laryngoscopy. Rather, it emphasizes the importance of distinguishing between the success of laryngoscopy and that of intubation. Furthermore, Cormack and Lehane described a grade IV where no part of the larynx was visible as an "impossible" intubation "except by special methods," but in contemporary practice, "special methods" perhaps not imagined in 1984 are now commonplace or even routine. The larynx unseen by direct laryngoscopy may be easily seen by indirect methods such as video laryngoscopy or flexible endoscopy. Thus intubation of the trachea when direct laryngoscopy yields a Cormack–Lehane IV may not be impossible; indeed, it may not even be difficult when an indirect method is used.[7,20] The Cormack–Lehane view continues to be useful as a description of the laryngeal view achieved, but it is no longer a surrogate for the ease of intubation.

Our terminology must clarify rather than obscure our outcomes. Laryngoscopy is performed to view the larynx; thus, the author believes that if the larynx cannot be seen, laryngoscopy has failed (irrespective of whether intubation has been achieved). A meta-analysis involving 50,760 adult patients with seemingly normal airway anatomy defined

"difficulty" by failure to see the larynx by direct laryngoscopy (Cormack–Lehane score of III or IV). The authors found that careful bedside assessment was at best moderately sensitive and specific in predicting this event.[23]

There are other nonbinary ways of describing difficulty with laryngoscopy, including the percentage of the glottic opening seen,[24] the number of attempts, intubation time, the number of operators, and the number of techniques required.[25,26] Using this author's definition, "failed (direct) laryngoscopy" is a common occurrence, even when our bedside evaluation is reassuring.

Most studies involving direct laryngoscopy do not distinguish between difficulty with laryngoscopy and intubation.[27] Indeed, many fail to even describe the device or technique that was employed. It is clear that poor clinical documentation does not adequately inform subsequent care providers or enable them to optimize clinical outcomes. Similarly, incomplete published descriptions of technique force assumptions that may be incorrect, lead to a miscalculation of the dimensions of the problems, and hamper the progress of clinical research. Clinical documentation should provide a complete description of the technique, the adjuncts required (*e.g.*, device used, stylet, "bougie" or tracheal introducer, external laryngeal manipulation, special positioning), and the outcomes achieved for each attempt.

Incidence of Difficult and Failed Laryngoscopy and Intubation

The incidence of failed laryngoscopy depends upon the device and technique employed, the patients studied, the care provider's expertise, the context of the encounter, and how failure is defined.[28,29] Acknowledging that there is little consensus on the definition of "difficulty" and that this author's preferred definition is not widely used, we must assess the literature critically. Using the definition of a "difficult intubation" as requiring more than three laryngoscopy attempts (device not specified) and a "failed intubation" as resulting in a wake-up or emergency surgical airway, it appears that there has been an encouraging trend toward fewer such events.[30] A recent study by Schroeder *et al.*[30] compared 2002–2008 and 2009–2014, and observed a fourfold reduction in "difficult intubation" (6.6 of 1,000 *vs.* 1.6 of 1,000 events) and a similar reduction in "failed intubation" (0.2 of 1,000 *vs.* 0.06 of 1,000 events). They did not distinguish between difficult laryngoscopy and intubation; neither did they identify the primary and rescue techniques, the number of attempts required, or complications other than dental injury, gastric aspiration, and the need for an emergency surgical airway. Although we can speculate that new technology and increased experience with these devices may have contributed to the apparent improvements, the study fails to provide the necessary evidence. Encouraging though this study might seem, patient safety may not have advanced as much as the study suggests.

When failed laryngoscopy is defined as the inability to see the larynx (*i.e.*, Cormack–Lehane score of III or IV), direct laryngoscopy failed in approximately 6%[31] of adult surgical patients and ranged from 6 to 27% in another systematic review.[32] (Curiously, Cormack and Lehane estimated that a Cormack–Lehane III view would be seen in 1:2,000 laryngoscopies.[18]) By contrast, an early GlideScope video laryngoscopy study observed Cormack–Lehane scores of III and IV in 3 and 4 of 728 patients, respectively.[23] Regarding prediction of difficulty when using "a standard [direct] laryngoscope," a recent Cochrane Systematic Review involving 133 studies and 844,206 participants and standard bedside airway assessments individually and in combination had limited sensitivity, higher specificity, and high variability and therefore needs to be used cautiously.[33] Systematic reviews were hampered by the high statistical heterogeneity of patient populations, definitions, and applications of "predictive tests," and laryngoscopic failure.

In addition to the importance of distinguishing between difficulties in laryngoscopy and intubation, a binary designation of difficulty (*i.e.*, easy or difficult) may be less useful than a continuous scale.[24,34,35] An intubation difficulty scale—although it should really have been termed a laryngoscopy difficulty scale—was proposed[35] and prospectively tested.[25] It is based upon seven parameters: the number of attempts, operators and techniques required, the Cormack–Lehane grade seen, required force applied, the need for external laryngeal manipulation, and vocal cord mobility. An intubation difficulty score of 0 was straightforward with no difficulties encountered and was seen in 55% of surgical patients. Minor and moderate difficulties were arbitrarily defined as intubation difficulty scores of 1 to 4 and more than 5, respectively. Minor and moderate difficulties were encountered in 37 and 7.7%, respectively, of 1,171 consecutive adult surgical patients using direct laryngoscopy. Two or three attempts were required in 9% of patients; more than three attempts were observed in 3%. There is little room for complacency. More focused attention to degrees of difficulty, rather than outright failure, may guide quality improvement, enhancing patient safety and direction for clinical research efforts.[36,37]

Systematic reviews have shown that the incidence of failed laryngeal visualization is significantly less when video laryngoscopy is used.[23,38–41] However performed, laryngoscopy and intubation are complex tasks requiring considerable experience. Early advocates of video laryngoscopy failed to appreciate the important distinction between obtaining a laryngeal view and successful tracheal intubation, although half the failed intubations occurred despite a Cormack–Lehane I view.[23] It is beyond the scope of this review to compare the characteristics and performance of different video laryngoscope devices,[42,43] but it would appear that even for experienced (direct) laryngoscopists, device-specific skill acquisition requires more practice than was previously assumed.[44]

Generally, laryngoscopies performed outside of the operating room are more likely to result in poor laryngeal views,[35] multiple attempts,[45] and a higher failure rate.[35,45–48] Reasons for this are multifactorial and relate to the care provider, training, experience, soiled airways, physiologic instability, inadequate equipment, insufficient time to prepare, to obtain medications, incomplete information, and physical access.[13]

Human Factors

It was estimated that human factors played a role in 40% of the adverse outcomes in the 4th National Audit Project. Using tools developed for monitoring oil and gas drilling operations, Flin *et al.*[49] interviewed anesthesiologists who had contributed cases with serious adverse outcomes to the 4th National Audit Project database. They identified several human factor errors that played a causal role in every one of the 12 events examined. These errors included erroneous actions, lack of situational awareness, and physical or procedural threats such as fatigue, stress, inadequate training for the task, poor communication, unfamiliarity with available tools, and reluctance to relinquish control. Error recovery, distractions, multitasking, and a hierarchical culture may also have played a role.

Prevention of and Preparation for Failure

Planning and Preparing

Given the above-mentioned performance obstacles, improved outcomes may result from prior rehearsals by clinical simulation aimed at improving technical skills and teamwork, discussion with the team of anticipated difficulties and contingency plans during a "preoperative checklist," familiarity with the location and operation of available resources, relevant algorithms, and cognitive aids. Attention to and correction of those factors that support an unsafe environment might also reduce patient harm.[14]

Our understanding of the difficult airway has evolved beyond a mere consideration of the anatomical predictors of difficulty[5] such as the Mallampati oropharyngeal view or its derivatives, thyromental distance, mouth opening, cervical mobility, dentition, and upper-lip bite test[50] that appear to be at best moderately sensitive and specific.[22,33,51] When planning and preparing to manage an airway, we should also take into consideration the circumstances under which the airway is being managed[52] and the patient's physiologic reserve[12] (table 1). A central lesson from the 4th National Audit Project was the advice that we should never fail to prepare for failure.[2] Cognitive performance deteriorates with stress, and failure in airway management can certainly result in fixation errors and perseveration, jeopardizing patient safety. Complex algorithms may not

be mentally accessible during such times. We must strive to enhance critical decision-making, improve our clinical skills, and facilitate efficient resource deployment.

Acquisition of Technical Skills

This review is not about training *per se*. However, proper training and practice are essential to acquire and maintain the technical skills, situational awareness, and team integration. Technical skills are not necessarily transferable from one device to another. Expertise with direct laryngoscopy does not impart competency with a video laryngoscope, an optical stylet, or a flexible endoscope. Evidence from the 4th National Audit Project showed that poor preparation for a difficult or failed airway was responsible for the majority of serious adverse airway outcomes.[2] Failure to adequately evaluate the patient leads to unanticipated difficulties. Inadequate training and occasional use of alternative techniques results in a lack of confidence and a reluctance to employ such techniques when they may be more appropriate. Competency with a narrow range of techniques and devices leads to the use of and persistence with ineffective strategies. When unfamiliar techniques are deployed, particularly under stressful circumstances, it may lead to the faulty conclusion that the failure lies with the device, rather than inadequate training and insufficient experience. However, even experienced laryngoscopists will encounter difficulties regardless of how we define it—inability to see the larynx, multiple or prolonged attempts, and outright failure. The wise laryngoscopist is likely to recognize earlier that persistence with and minor adjustments using the wrong tool or technique have a low probability of success. The lack of comfort with alternative devices is more likely to result in multiple attempts with the same device, converting a cannot intubate to a "cannot intubate, cannot oxygenate" (CICO) situation.

Technical skills should be acquired progressively, beginning with manikin training and moving through airway workshops, cadaver training, and supervised performance involving low-risk patients to independent management of patients with anatomical, physiologic, and contextual challenges.[53] Although airway rotations[54,55] and advanced airway fellowships are increasing, many training programs still provide insufficient experience with a wide array of techniques.[56] In addition, many training programs do not distinguish between experience and expertise.[55] Practitioners who reserve alternative devices for airway rescue are unlikely to acquire or maintain competence, much less proficiency. They are unlikely to appreciate the subtleties of various devices and techniques or be comfortable using them in a rapidly deteriorating setting. If difficulties are encountered and the care provider has not made an adequate effort to become proficient with rescue techniques, patients may be injured, and a medical legal defense may be difficult to support. Comfort with a supraglottic airway, video laryngoscope and flexible endoscopic intubation are considered

Table 1. Anatomical, Physiologic, and Contextual Predictors of a Difficult Airway

Anatomical Difficulties[97]	Facemask Ventilation[64,98,99]	SGA*[64,100]	Direct Laryngoscopy[8,65]	Video Laryngoscopy†,[64,101]	FM Ventilation + DL‡[102]
	BMI ≥ 30 kg/m²	Higher BMI	History of failure	Supine sniffing position	BMI ≥ 30
	Beard	Age > 45 yr	Prominent upper incisors	Provider	Age > 45 yr
	Snoring	Male sex	Overbite	Cardiac *vs.* gen/gyn/uro/vasc surgical patient	Male sex
	History of OSA	Reduced thyromental distance	Inability to protrude mandible	ENT/oral surgical patient	Neck irradiation or neck mass
	Age ≥ 57 yr	Thick neck	Reduced interincisor distance	Reduced interincisor distance	Reduced thyromental distance
	Mallampati ≥ III	Poor dentition	Mallampati ≥ III		Presence of teeth
	Limited jaw protrusion	Smoker	High-arched palate		Presence of beard
	Neck irradiation	Surgical table rotation	Reduced TMD		Thick neck
			Short neck		OSA
			Reduced cervical range of motion		Reduced cervical range of motion
			Reduced compliance of mandibular space		Reduced jaw protrusion
			Lingual tonsil hyperplasia[105]		
Physiologic difficulties	Hypoxemia				
	Hypercapnia/acidosis				
	Increased risk of regurgitation				
	Hemodynamically unstable				
Contextual difficulties	Geographic location of event				
	Access to patient				
	Resources/staff/drugs				
	Emergent nature				
	Coordination of team				

*Laryngeal Mask Airway Unique. †Hyperangulated video laryngoscope (C-MAC D-blade; GlideScope). ‡More than three attempts at direct laryngoscopy (DL). BMI, body mass index; ENT, ear, nose, and throat; FM, face mask; gen, general surgical; gyn, gynecological surgical; OSA, obstructive sleep apnea; SGA, supraglottic airway; TMD, thyromental distance uro, urological surgical; vasc, vascular surgical.

core skills and should be part of the armamentarium of every anesthesiologist.[10,14] Similarly, every anesthesiologist should be prepared to perform an emergency surgical airway or front of neck access (FONA) should other measures of establishing an airway fail.

Most anesthesiologists will rarely if ever actually encounter a cannot intubate, cannot oxygenate situation. They may be ill-prepared to perform a front of neck access, and the 4th National Audit Project demonstrated that when called upon to do so, anesthesiologists performed poorly.[2] When a cricothyroidotomy is learned and practiced on a model, anesthesia trainees demonstrated greater compliance with the ASA difficult airway guidelines in a simulated cannot intubate, cannot oxygenate setting.[57] Recently, a three-dimensional–printed anatomical cricothyroidotomy simulator was described, and its plans were placed in the public domain.[58] Anesthetized animals,[59] animal preparations, and human cadavers have also been used to train and practice the technique.[60]

Nontechnical Preparation by Simulation

Low-fidelity simulation includes the use of airway manikins or partial-task trainers,[61] which at best promote dexterity and familiarity with devices and techniques.[62] High-fidelity simulation offers an opportunity to develop team coordination, cognitive, and motor skills to manage common and rare clinical situations. These can be rehearsed, reviewed, and replayed, to increase familiarity and compliance with existing guidelines or to refine approaches to simulated challenges, all without the risk of causing patient harm.[53,56] Compared with nonsimulation educational methods, airway simulation enhances skill acquisition and patient outcomes.[63] The number of critical steps completed by anesthesia trainees during a simulated front of neck access was assessed by video analysis. The participates were either guided or not guided from a "read-aloud card." Although progress through the scenarios took longer when the cards were used, there were fewer delays in calling for help, fewer omissions of neuromuscular blockers, and fewer missed steps in the read-aloud cohort.[64] It is unclear whether read-aloud cards would enhance the performance of other tasks in a clinical setting.

Guidelines, Algorithms, and Cognitive Aids

Various airway guidelines and algorithms have been developed to deal with the anticipated[65,66] and unanticipated

difficult airway.[5,10,14,15,17,66–68] Their authors endeavored to produce high-quality, evidence-based recommendations, although these were often lacking because of the difficulties inherent in conducting adequately powered, randomized, controlled, and blinded studies on uncommon emergency events. Accordingly, most recommendations are largely based upon expert opinion. A detailed comparison of airway guidelines is beyond the scope of this review but may be found elsewhere.[69–72] None of the guidelines or algorithms is meant to define the standard of care but rather to serve as a guide, assisting the airway practitioner in rapid decision-making, especially in rarely encountered situations. Quite apart from their inherent validity, algorithms that are excessively complex are likely to be of limited value in a situation that is both urgent and stressful.

Chrimes[73] with Fritz[74] developed the vortex approach to airway management, a cognitive aid intended to be used by anesthesiologists, as well as emergency and critical care physicians in real time. It represents airway management as a conceptual vortex with a safe "green zone," a rim that descends into a darkening blue funnel (figs. 1 and 2).[73] The tool's content is deliberately minimal to reduce cognitive clutter, the emphasis being on prior training and the promotion of team involvement. The details are simple—there

are three nonsurgical approaches, referred to as "lifelines" to provide oxygenation: facemask, supraglottic airway, and tracheal intubation. (Although the focus of this review is on laryngoscopy and intubation, the reader should not lose sight of the reality that safe airway management revolves around the maintenance of adequate alveolar ventilation, however this is achieved.) As the team approaches a maximum of three optimized attempts with each of the lifelines, the team should declare and be prepared for a surgical intervention, which they refer to as "CICO rescue" and herein has been called front of neck access. Thus, the team anticipates and prepares for this situation even before it is declared. This is important considering the time required for its implementation. The concept of the "green zone" is intended to emphasize that maintaining (and confirming) alveolar oxygenation is more important than how it is achieved; departure from the green zone represents a threat, whereas reentry indicates that a critical situation has been averted. The vortex approach does not compete with existing algorithms. It was designed to complement and facilitate their implementation in real time.[74] Useful training materials, downloads, checklists, videos demonstrating cognitive and performance errors, and links to downloadable signs and apps may be found on the vortex website.[74]
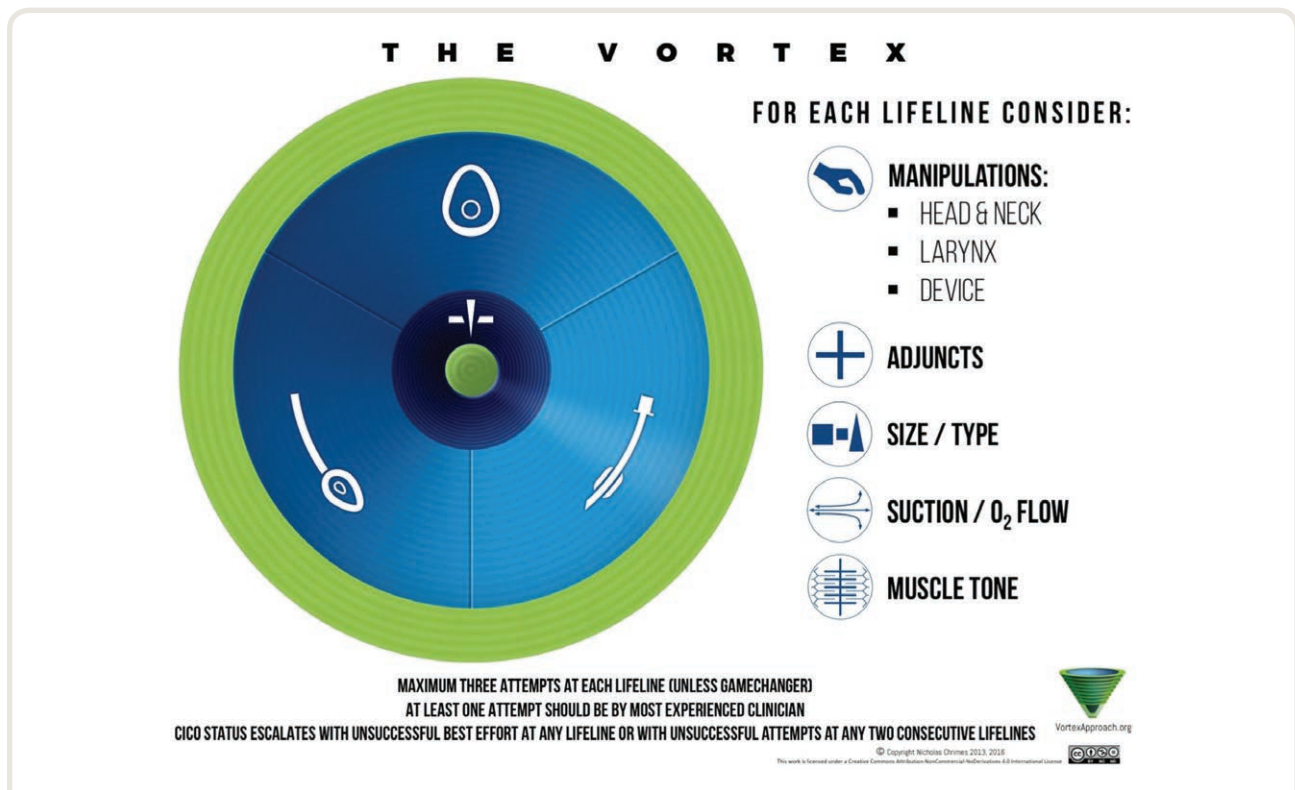

Fig. 1. The image displays the vortex airway approach from the top. The *green zone* is a "safe zone": the lungs can be adequately ventilated, and the oxygen level remains stable. There are three nonsurgical "lifelines" to deliver oxygen: facemask, supraglottic airway, and a tracheal tube. Optimizing measures are depicted to the *right* of the image. As oxygenation becomes compromised, the color changes to *blue* and intensifies, approaching the center, where oxygenation is failing despite optimization efforts. This is referred to as cannot intubate, cannot oxygenate (CICO), and it demands anticipation and a prompt surgical intervention (CICO rescue). Reprinted with permission from Nicholas Chrimes.
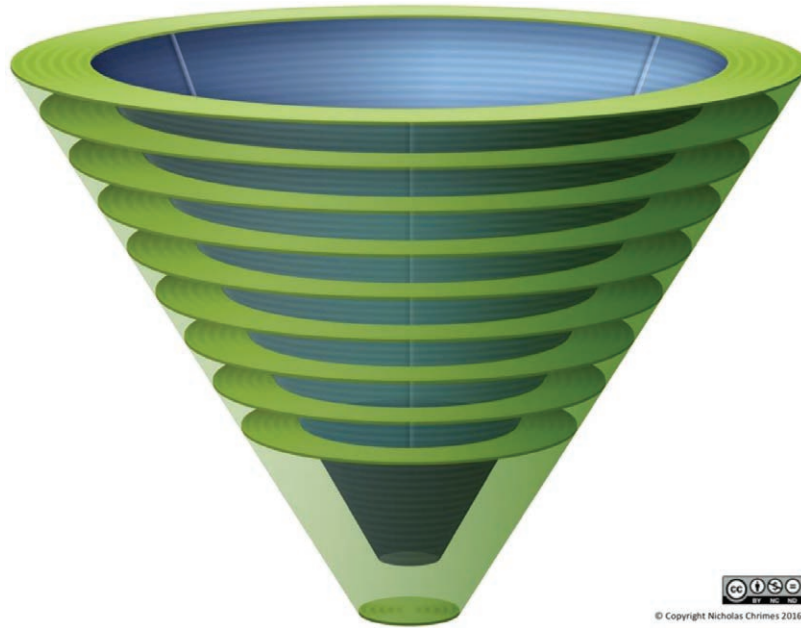
Fig. 2. The image displays the vortex from the side. As predicted by the shape of the oxyhemoglobin dissociation curve, when oxygenation begins to fail, the descent into the vortex accelerates, demanding anticipation and prompt action. Reprinted with permission from Nicholas Chrimes.

Particularly recommended is a powerful reenactment of the Elaine Bromiley case.[75]

Preoxygenation/Apneic Oxygenation

Preoxygenation[76,77] should be provided to all patients before the induction of anesthesia,[14] and "per–oxygenation"[78] (or apneic oxygenation) with high–flow nasal cannula has been shown to delay the development of hypoxemia.[78] In the absence of total airway obstruction, heated, humidified oxygen using specialized cannulae, heater, humidifier, and a high–flow oxygen delivery device (THRIVE, Fisher and Paykel, New Zealand) at up to 70 l/min has been demonstrated to provide tolerance to apnea for prolonged periods with a reduced rate of carbon dioxide accumulation. High–flow oxygenation (5 to 15 l/min) with conventional nasal or buccal cannulae[79] can also be applied after the loss of consciousness and will delay the onset of hypoxemia during airway management.

Articulation of Airway Management Plans

There is a growing appreciation that the airway management plan should strive to achieve first pass success[80]: "A suboptimal attempt is a wasted attempt and having failed, the chance of success declines with each subsequent attempt."[14] Optimization includes preoyxgenation/apneic oxygenation, positioning, selection of the device most likely to succeed in the present circumstance, the use of stylet or introducer,[48,81] and adequate neuromuscular relaxation.[14,82–84] Relaxation facilitates all airway maneuvers including facemask ventilation, supraglottic airway insertion and ventilation, laryngoscopy, intubation, and front of neck access.

The preoperative checklist should advise the team whether difficulties are anticipated and ensure that the location and availability of additional resources are known. Those resources and backup plans should be specified. If the first attempt has been optimized and is unsuccessful, the team should be alerted to the possibility of a problem. Each effort carries an incremental danger of desaturation, regurgitation, airway injury, and the risk of converting a cannot intubate situation to a cannot intubate/cannot oxygenate situation. Furthermore, unless someone else is delegated to maintain the depth of anesthesia, the focus of attention by the laryngoscopist and the passage of time may increase the risk of an inadequate depth of anesthesia, accidental awareness, and hemodynamic stress.

Airway management is the anesthesiologist's preeminent domain, and no single device will be appropriate to every situation. Therefore, our standard skill set must include direct laryngoscopy, video laryngoscopy (Macintosh and hyperangulated styles), supraglottic airway, flexible endoscopic assisted intubation, and the ability and willingness to perform a front of neck access. It is incumbent upon training programs and institutions to ensure that trainers and trainees have the opportunity to acquire the requisite skill in an appropriately structured and supervised fashion.[10,14–16]

Although "plan A" should be chosen with an expectation of success, plans B and C should exploit potential weaknesses of each prior attempt. The team should be aware of these backup plans, the triggers that invoke them, and the location of personnel and equipment they may require.

Management

Failed Laryngoscopy and Intubation but Oxygenation Is Adequate

Even when our first laryngoscopy attempt was thought to be our best attempt, it may fail. Before withdrawing the laryngoscope, the laryngeal view may be enhanced by external laryngeal manipulation[85] or a head lift.[86]

The laryngoscopist should stop and recall the primary goal of airway management. Failure to intubate is not an emergency if alveolar ventilation and oxygenation can be maintained. Preoxygenation will delay the onset of desaturation, and recognition of inadequate alveolar ventilation may be delayed if oxygen saturation is maintained. (The Japanese guidelines rely heavily on the capnographic waveform to identify the adequacy of alveolar ventilation.[15]) A prudent physician will pay attention to all the clinical signs; however, stress and cognitive overload may compete with sober decision-making. We must endeavor to make use of the clinical signs as well as the objective and quantitative evidence provided by capnography and oximetry in assessing how well we are accomplishing alveolar ventilation. When alveolar ventilation or oxygen saturation is suboptimal, we should quickly determine what measures might improve this, including repositioning the head and neck, elevating the back of the bed to level the ear with the sternal angle,[87] a jaw thrust, two-handed ventilation,[88] insertion of an oral and/or nasal airway, or insertion of a supraglottic airway. A *familiar* and readily available alternative device may facilitate intubation.

When facemask ventilation is difficult, preoxygenation may postpone hypoxemia; however, persistent and possibly more energetic attempts at overcoming partial airway obstruction may lead to gastric distension, regurgitation, and aspiration. Efforts must quickly be directed toward relieving obstruction. When measures such as a jaw thrust, two-handed ventilation, and oral/nasal airway fail, early conversion to a supraglottic airway should be considered. When laryngoscopy has failed, the need for tracheal intubation must be critically reassessed. A prior decision to intubate does not obligate the airway manager to pursue that strategy after identifying unanticipated difficulties. A supraglottic airway may have averted an emergency. The airway manager must then decide whether it should be used as a destination airway or a bridge to other strategies.

With the urgency eliminated, the necessary equipment and personnel can be recruited, and the airway manager can

pause and reflect. In experienced hands, video laryngoscopy with a hyperangulated blade has a high success rate after failed direct laryngoscopy.[20,21] Use of a supraglottic airway as an endoscopic conduit to tracheal intubation is an enticing idea,[89,90] but it is not always successful,[7] and prior (elective) experience is highly recommended. After an unsuccessful attempt at laryngoscopy, it may be apparent that the failure to see the larynx can be overcome using an indirect technique such as video laryngoscopy. If oxygenation can be sustained and the skill and resources are available, recent guidelines advocate visualized tracheal intubation using video laryngoscopy in preference to blind methods such as a tracheal introducer (traditionally referred to as a bougie).[14]

Notwithstanding the above comment, many practitioners will elect a blind attempt at intubation using a tracheal introducer if the epiglottis can be identified (Cormack–Lehane IIb or IIIa view[4]). This should not be attempted if the epiglottis cannot be seen or elevated.[14] Commonly used signs of tracheal entry such as "tracheal clicks" and the "hold-up sign" may not be reliable and are potentially dangerous, particularly with single-use introducers.[14,91–93] Blind advancement of the tracheal tube over the introducer may also be unsuccessful or traumatic. If the larynx cannot be visualized, and difficulty is experienced inserting a supraglottic airway, a "bougie-aided" placement technique might be considered. A well-lubricated introducer is inserted *via* the airway drainage port. The introducer is deliberately advanced into the proximal esophagus under visual control, and the airway is advanced over or along with the "bougie."[94]

If alveolar ventilation can be maintained, the timing of a call for help is a matter of clinical judgment. It should be based upon the patient's condition, the airway manager's experience, logistics, the availability of additional equipment and personnel, and the expectation of success with that the next technique.

If alveolar ventilation is maintained, and intubation is desirable but cannot be achieved, wakening the patient may be an option. This becomes increasingly difficult as the number of attempts at airway management mount. If a decision is made to persist, the airway manager should then ensure that neuromuscular blockade is adequate. This is a pivotal decision and runs counter to our professional instincts and traditional teaching; however, in the absence of neuromuscular blockade, laryngoscopy, intubation, facemask,[95] and supraglottic ventilation and ultimately the performance of front of neck access are more challenging.[14,82]

Sugammadex may reverse nondepolarizing neuromuscular blockade but will not reverse an obstructed[96] or traumatized airway[97] that could be a consequence of "multiple attempts" at airway instrumentation. If, after sugammadex administration, oxygenation/ventilation can still not be achieved, subsequent efforts to achieve nondepolarizing neuromuscular blockade will be antagonized potentially, making ventilation, laryngoscopy, intubation, or an emergency front of neck access even more difficult.[98]

A limited number of additional attempts at maintaining oxygenation by facemask, supraglottic airway, or tracheal tube can be justified. Given the increasing risk and diminishing probability of success with multiple attempts, a consensus is emerging to limit the number of attempts to three with each modality (*i.e.*, facemask, supraglottic airway, and laryngoscopy). When trainees are involved, the mentor must assume responsibility to intervene at an appropriate moment. This may create an ethical conflict between our fiduciary duty to the patient and our obligation to provide learning opportunities to our trainees,[99] but our ultimate obligation is to minimize patient harm. The Difficult Airway Society has recommended allowing one additional laryngoscopy attempt when a more experienced colleague becomes available.[14]

A recent retrospective analysis of 1,619 failed laryngoscopies involving 1,009 anesthesia providers at seven U.S. academic centers made several interesting observations. Between 2004 and 2013, failure of *direct* laryngoscopy often resulted in a switch to alternative devices after only a single attempt. Five rescue techniques were employed sufficiently often to be studied (video laryngoscopy, flexible bronchoscopy, lightwand intubation, supraglottic airway, and use of an optical stylet). During this period, there was a significant increase in the use of video laryngoscopy at the expense of all other techniques. Bronchoscopic rescue went from approximately 30 to 5%. Use of video laryngoscopy went from approximately 23 to 83%. Although six devices were included among the video laryngoscopy, only the GlideScope and C-MAC were sufficiently represented to permit a meaningful interpretation of the data, although the specific models were not reported. The overall success rates associated with the most commonly used video laryngoscopes were 1,032 of 1,122 (92%; 95% CI: 90 to 93) for the GlideScope and 61 of 66 (92%; 95% CI: 83 to 97) for the C-MAC. Intubation using a flexible bronchoscope was associated with a success rate of 78% (95% CI: 71 to 83). Caution should be used when interpreting this retrospective study; the patients may have been dissimilar, and video laryngoscopes with different blade designs may yield different outcomes. In addition, they were not rescued by randomly assigned devices. Clinicians are most likely to rely on devices and techniques with which they are most experienced and have enjoyed success.[7]

A recent Cochrane Systematic Review evaluated 64 randomized controlled trials involving more than 7,040 patients comparing direct and video laryngoscopy. The study found that video laryngoscopes provided better laryngeal views and were associated with fewer failed intubations, greater ease of use, and less airway trauma.[37] The literature is rapidly expanding and complicated by heterogenity. It must be interpreted cautiously given the numerous devices (not all of which are equivalent), used in a variety of clinical settings (*e.g.*, infants, adults, obese patients, emergency and critical care settings, consecutive *vs.* selected patients, as a primary or rescue device, awake or postinduction), by laryngoscopists with different skill levels, training and experience, and using different clinical outcomes (*e.g.*, first past success, ultimate success, time to tracheal intubation and complications).

Failed Laryngoscopy, Failed Intubation, Failed Oxygenation: Cannot Intubate, Cannot Oxygenate

Cannot intubate, cannot oxygenate represents the inability to intubate and a failure to provide adequate alveolar ventilation. The latter is recognized by a falling (or nonreassuring) oxygen saturation, the lack of chest expansion, or satisfactory capnographic tracing. Early declaration of cannot intubate, cannot oxygenate and a call for help should alert the team that a problem exists or might soon develop. We must discourage unnecessary distractions and mobilize personnel and equipment. A nearby difficult airway cart should be brought. The laryngoscopist must be familiar with its contents and how and when to use them. The cart must contain all the required equipment to perform basic and rescue maneuvers and should be organized so as to present the equipment in a logical sequence, thereby functioning as a visible and cognitive aid (fig. 3).

When help arrives, they must be empowered to assist. Stressful situations may result in physical exhaustion, cognitive overload, and fixation errors with persistent attempts using ineffective strategies. The "ticker" does not start over; it continues. The number of attempts at managing the airway is cumulative.

All the maneuvers to optimize facemask ventilation and supraglottic airway insertion and ventilation, as well as laryngoscopy and intubation, should be reviewed. The adequacy of neuromuscular blockade should be confirmed. Although high-flow nasal oxygenation is more effective at preventing than treating desaturation, there is little to be lost by its implementation.

An additional attempt at facemask ventilation or ("bougie-guided") supraglottic airway placement can be made, and if successful, a rational decision can be made about how best to proceed. This might involve wakening the patient, continuing with a supraglottic device, attempting a conversion to a tracheal tube, or an urgent surgical airway, performed by an experienced surgeon.

Verbal status declarations by the airway manager and anticipation by the team increase the likelihood of coordinated action. If the above attempts are unsuccessful, an emergency front of neck access will be necessary and must be so declared. Preparation for this can be concurrent with other attempts by other means provided there are sufficient operators. If help has not already been called, it should be.

Front of Neck Access

The ASA Practice Guidelines for Management of the Difficult Airway make recommendations regarding when
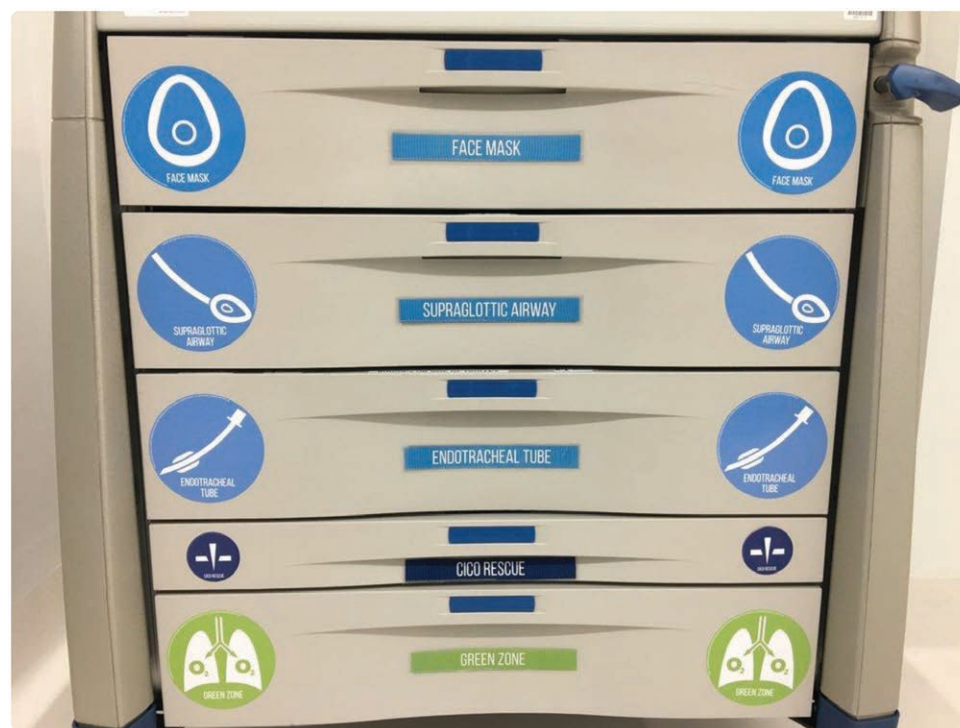
Fig. 3. A difficult airway cart. This difficult airway cart is well organized. Each drawer is clearly identified with recognizable icons used consistently by the vortex airway approach. The contents of the individual drawers can be determined by the institution, but they should be well organized to function as cognitive and visual aids, clearly labeled and familiar to stakeholders. CICO, cannot intubate, cannot oxygenate. Reprinted with permission from Nicholas Chrimes.

but not how front of neck access should be performed.[5] Most anesthesiologists will have never performed this and thus cannot rely on prior clinical experience. Furthermore, we know from the 4th National Audit Project that anesthesiologists perform this emergent task poorly.[2] It is generally agreed that under most circumstances, the anesthesiologist must take responsibility for obtaining an airway. In a stressful, time-sensitive setting, the method must be simple; more importantly, it requires prior training.[10,14]

Anesthesiologists agree that the cricothyroid membrane is the most accessible location for emergency front of neck access; however, often its identification is challenging, particularly in females, parturients, and obese patients.[100,101] Ultrasonographic identification can be performed,[100,102] but this is difficult in an emergency setting. Because the difficult airway cannot always be anticipated, identification of the cricothyroid membrane should be part of the initial airway assessment. It has generally been felt that anesthesiologists are more comfortable with a needle–guidewire–cannula (Seldinger-type approach) than use of a scalpel. Thus, percutaneous techniques were probably more widely embraced by anesthesiologists. Kristensen *et al.*[103] recently reviewed the literature, and although many of the published reports were conducted in the prehospital arena

and performed by military and emergency medical technicians, emergency physicians, and surgeons, the outcomes with the surgical approach have generally proven superior to a Seldinger technique. The surgical approach may consist of (1) a scalpel/finger/tracheal tube or (2) a scalpel/tracheal introducer ("bougie")/tracheal tube. The surgical approach also resulted in higher success rate and fewer complications among trained medical students performing on cadavers compared with a Seldinger technique (Melker cricothyroidotomy, Cook Medical, USA) and QuickTrach II (VBM, Germany).[60] The Difficult Airway Society Practice Guidelines promoted the surgical approach, motivated largely by a desire to encourage standardization. The recommended technique is described in graphic detail.[14] (Fortunately, clinical experience in infants and small children is limited and has been extrapolated from adult recommendations or experimental results on small animals.[103,104])

Equipment for a scalpel cricothyroidotomy is simple and readily available: a No. 10 blade scalpel, a bougie with a coudé tip, and a 6-mm cuffed tracheal tube. The provider should continue efforts to oxygenate the patient while the following are performed: a right-handed operator should stand on the patient's left side; the thumb and index finger of the nondominant hand grasp the hyoid cartilage and slide down to

the thyroid cartilage. This is referred to as a "laryngeal hand-shake." Slide down further to identify the cricoid cartilage between the thumb, index, and middle fingers (fig. 4).

If the cricothyroid membrane can be identified, using your dominant hand (fig. 5A), a transverse stab incision is made through the membrane (fig. 5B), pulling the blade toward you. If the cricothyroid membrane cannot be identified, a long midline vertical incision is made, dissecting bluntly with fingers to identify and stabilize the thyroid cartilage and cricothyroid membrane. Once identified, a transverse incision is made through the cricothyroid membrane, drawing the blade toward you. The blade is rotated 90° with the sharp edge pointing down (fig. 5C). The blade is transferred to the nondominant hand, keeping it perpendicular to the skin and maintaining gentle traction on the blade, creating an opening to the trachea.

The coudé tip of the bougie is inserted along the side of the blade with your dominant hand, directing it distally approximately 10–15 cm into the trachea (fig. 5D). The scalpel blade is removed, and the trachea and bougie are stabilized with your nondominant hand. Someone is assigned to hold the protruding end of the bougie. A lubricated 6-mm tracheal tube is gently advanced over the bougie (fig. 5E), rotating the tracheal tube if necessary. The cuff is inflated and the bougie is removed. The tube position is confirmed by capnography and auscultation. Ventilation is restored, and the tube is secured.

Mitigation of a Recurrence

Extubation Strategy

When difficulties have been encountered and a disaster has been averted, it is important to ensure that those charged with the patient's subsequent care are fully apprised of the problems encountered. Despite the seemingly appropriate timing of extubation, some patients will require reintubation as a result of hypoxemia, hypoventilation, airway obstruction, or the need to provide airway protection. Certain patients are at an increased risk of requiring reintubation because of diminished pulmonary reserves. Still other patients may suffer harm because they are at increased risk that a required reintubation will be difficult. An emergent reintubation is likely to be more difficult than one attempted electively, when the conditions had been optimized. Accordingly, an extubation strategy should maximize the likelihood of success should reintubation be required.[5,105,106] Strategies include delaying extubation, insertion of an airway exchange catheter, substitution of the tracheal tube with a supraglottic airway with a trial of spontaneous ventilation, or occasionally an elective tracheostomy.[105,106]

Communication

What do patients and subsequent care providers need to know to minimize future difficulties at the time of extubation/decannulation or reintubation? They need to know whether or not the problems were anticipated, whether or not difficulties were encountered with ventilation and oxygenation and how these were dealt with, and what devices were attempted successfully and otherwise. The information should be transmitted not only to the subsequent care providers but to the patient in such a way that they appreciate its importance to minimize a recurrent event. If extubation is deferred, it is advisable that extubation be performed in the presence of an airway expert.

If a patient fails to understand why this information is important, they may not think to communicate it to future
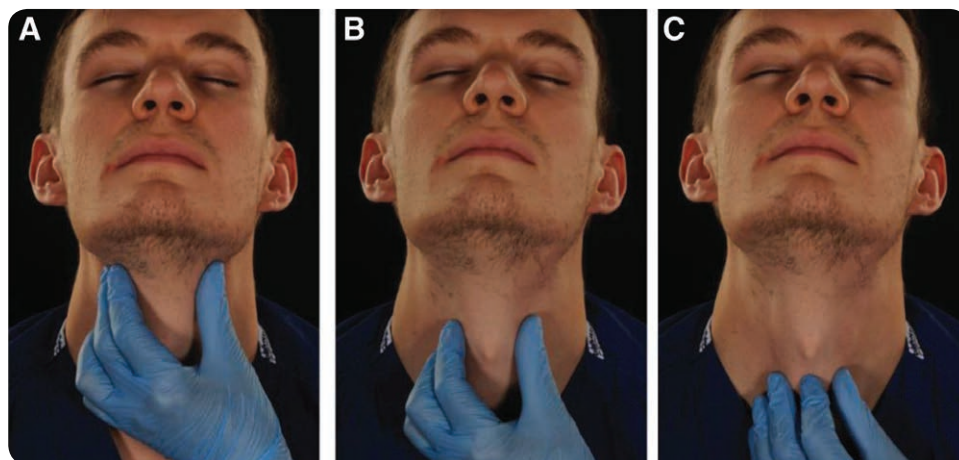

Fig. 4. The laryngeal handshake. This concept attempts to identify the hyoid, thyroid, and cricoid cartilages using the nondominant hand. It may help to locate the cricothyroid cartilage if an emergency surgical airway (cricothyroidotomy; cannot intubate, cannot oxygenate [CICO] rescue; front of neck access) is required.
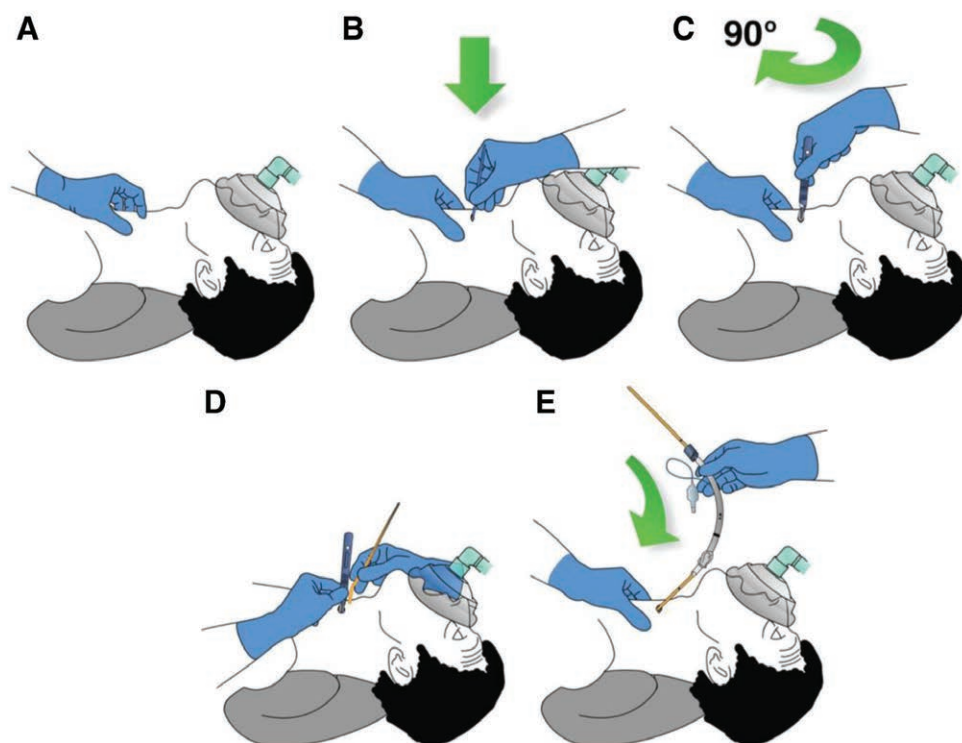
Fig. 5. Recommended technique for a scalpel, bougie, catheter approach to an emergent front of neck access.

anesthesia providers. Care may also be provided elsewhere or be of an emergent nature, making access to the anesthetic records challenging. While in the hospital, the patients may be provided with an airway alert bracelet or an "electronic flag" on their medical record. Upon discharge from the hospital, they can be provided with a "difficult airway letter" explaining the problems encountered and how they were dealt with. If they are unable to present the letter, it is of limited value. Registration with an accessible database such as MedicAlert (http://www.medicalert.org. Accessed March 8, 2018.) is recommended.[107]

Conclusions

Although this review focuses on failure, our best efforts should always be directed toward its avoidance. The primary goal of airway management is the maintenance of oxygenation. New techniques in preoxygenation and apneic oxygenation may forestall hypoxemia. Optimization of facemask and supraglottic airway use may maintain oxygenation; use of video laryngoscopy, an optical stylet, or flexible bronchoscopic intubation with or without a supraglottic airway conduit may be very helpful. Airway providers must be comfortable with an array of techniques. These techniques should be progressively incorporated into our clinical practice by simulation, workshops, airway conferences, and mentoring by those with greater expertise. We

should strive to optimize every airway intervention because each suboptimal effort wastes precious time and increases the risk of patient harm. We must be aware of the prevailing anatomical, physiologic, and contextual challenges and recognize when our efforts are not succeeding. If ventilation is ineffective, the situation can deteriorate very quickly once saturation begins to fall. At this point, our motor and cognitive performance may be compromised. Calling for help early should summon the necessary equipment, additional expertise, cognitive aids, and hopefully coordinated teamwork leading to better patient outcomes.

Competing Interests

The author declares no competing interests.

Correspondence

Address correspondence to Dr. Cooper: University of Toronto and University Health Network, Toronto General Hospital, 200 Elizabeth St. 3EN-421, Toronto, Ontario M5G 2C4, Canada. richard.cooper@utoronto.ca. Information on purchasing reprints may be found at www.anesthesiology. org or on the masthead page at the beginning of this issue. ANESTHESIOLOGY's articles are made freely accessible to all readers, for personal use only, 6 months from the cover date of the issue.

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