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Airway Management in Critically Ill Patients

Donald E. G. Griesdale · William R. Henderson · Robert S. Green

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Abstract In critically ill patients, endotracheal intubation is associated with a high risk of complications, including severe hypoxemia and hypotension. The purpose of this review is to discuss the definitions, complications, airway assessment, and patient optimization with respect to these patients. In addition, we present different approaches and techniques to help secure the airway in critically ill patients. We also discuss strategies to help minimize the risk of a difficult or failed airway and to mitigate the severe life-threatening complications associated with this high-risk procedure.

Keywords Intubation · Intratracheal · Critical care · Critically ill

D. E. G. Griesdale · W. R. Henderson
Division of Critical Care Medicine, Department of Medicine, University of British Columbia, Vancouver, BC, Canada

D. E. G. Griesdale · W. R. Henderson
Program of Critical Care Medicine, Vancouver General Hospital, Vancouver, BC, Canada

D. E. G. Griesdale (✉)
Department of Anesthesia, Vancouver General Hospital, Jim Pattison Pavilion, 855 West 12th Avenue, 2nd Floor, Room 2438, Vancouver, BC, Canada
e-mail: dgriesdale@post.harvard.edu

D. E. G. Griesdale
Department of Anesthesia, Pharmacology and Therapeutics, University of British Columbia, Vancouver, BC, Canada

D. E. G. Griesdale
Centre for Clinical Epidemiology and Evaluation, Vancouver Coastal Health Research Institute, Vancouver, BC, Canada

R. S. Green
Department of Emergency Medicine, Dalhousie University, Halifax, NS, Canada

R. S. Green
Division of Critical Care Medicine, Department of Anesthesia, Dalhousie University, Halifax, NS, Canada

Introduction

In the operating theater, endotracheal intubation (ETI) is done generally in controlled circumstances by anesthesiologists and carries a low risk of complications [1]. In contrast, ETI in the intensive care unit (ICU) is often performed under suboptimal conditions, in patients with limited physiologic reserve [2] and by individuals who have variable levels of expertise in airway management [3, 4]. It is thus not surprising that ETI in critically ill patients is associated with a very high risk of both difficult laryngoscopy and difficult intubation [3, 5, 6]. In addition, up to 54% of critically ill patients who undergo ETI may experience a complication [7]. Even in ICUs where the majority of intubations are done by highly skilled individuals (experienced anesthesiology residents or staff intensivists), severe life-threatening complications have been reported in 28% of cases [5].

Definitions

There is no uniform definition of the difficult airway specific to critically ill patients. Although designed for use primarily by anesthesiologists in the elective operating room setting, the American Society of Anesthesiologists (ASA) has definitions relating to difficult airway and its management that may be useful (Table 1) [8]. Appropriate

Table 1 Airway management definitions and incidence

Term	Definitions	Reference	Incidence in OR	Incidence in ICU
Difficult airway	Clinical situation in which a conventionally trained anesthesiologist experiences difficulty with face mask ventilation of the upper airway, tracheal intubation, or both	ASA guidelines [8]		
Difficult mask ventilation	It is not possible for the anesthesiologist to provide adequate face mask ventilation because of one or more of the following problems: inadequate mask seal, excessive gas leak, or excessive resistance to the ingress or egress of gas	ASA guidelines [8]	1.2–1.4%	Unknown
	Mask ventilation that is inadequate to maintain oxygenation, unstable mask ventilation, or mask ventilation requiring two providers	Kheterpal [53], Han [54]		
Impossible mask ventilation	Absence of end-tidal CO_2 measurement and lack of perceptible chest wall movement during positive-pressure ventilation attempts despite airway adjuvants and additional personnel.	Kheterpal [53], Han [54]	0.05–0.16%	Unknown
Difficult intubation	Tracheal intubation requires multiple attempts in the presence or absence of tracheal pathology	ASA guidelines [8]	1–8% [55, 56]	6.6–22% [1–3, 57]
Difficult laryngoscopy	It is not possible to visualize any portion of the vocal cords after multiple attempts at conventional laryngoscopy. This would correspond to a Cormack-Lehane glottic view of 3 or 4 [11]	ASA guidelines [8]	6.1–10.1% [58–60]	11–12% [1, 2]

OR operating room; *ICU* intensive care unit; *ASA* American Society of Anesthesiologists

definitions are useful not only for research purposes, they are essential for communication between practitioners. For example, identifying a patient who is previously known to be a difficult laryngoscopy will help guide future airway management.

Airway Assessment and Documentation

As most intubations in the critically ill are urgent rather than emergent, there is usually time for patient assessment and optimization. A targeted airway history and physical examination should be performed to help assess for anticipated difficulty with both mask ventilation and ETI. An airway assessment should be performed on every patient regardless of whether ETI is required at this point. A prior history of either a difficult airway or previous fiber-optic intubation should alert the physician to a possible difficult airway. An evaluation tool, with the acronym LEMON, has been developed to help stratify patients with respect to anticipated difficulty of ETI [9]. The LEMON method has been validated in patients presenting to the emergency department at a teaching hospital in the UK. Despite this, our ability to predict difficulties with ETI is poor. In isolation, non-reassuring physical exam features have a low to moderate sensitivity (20–62%) and a moderate to fair specificity (82–97%) [10]. Thus, we will miss many patients with difficult intubations because they may have "normal" exams. Combining tests only incrementally improves physical examination performance (e.g., Mallampati III or IV *and* a decreased thyromental distance). Factors associated with difficult mask ventilation and ETI are listed in Table 2.

At our institution we use a standardized form to document the airway assessment and management for each patient admitted to the ICU. The preintubation airway assessment record (Fig. 1) has a history and clinical exam component that incorporates a modified version of the LEMON criteria. It is completed by a respiratory therapist when a patient is first assessed by the ICU team. The postintubation airway assessment record (Fig. 2) is completed by the respiratory therapist either following intubation by the ICU team or by using the patient's records if the patient was intubated elsewhere. Thus, if the patient

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Pre Intubation Airway Assessment Record

Patient label

Individual Completing Pre Intubation Airway Assessment Record:__________________________

Date of Evaluation: _______(day)/________(mth)/________(year)

Patient History:

Has the patient had a previous difficult intubation? (i.e. Fiberoptic) **Comment:**____________________	☐ yes	☐ no
Does the patient have an unstable c-spine or previous spinal fusion? **Specifics:** ____________________	☐ yes	☐ no
Does the patient have a history of OSA with CPAP use? **Any treatment:** ____________________	☐ yes	☐ no
Does the patient have a history of burns to the head or neck? **Comment:**____________________	☐ yes	☐ no
Does patient have severe rheumatoid arthritis? **Comment:**____________________	☐ yes	☐ no
Has the patient had previous airway surgery or a previous tracheostomy? **Specifics:** ____________________	☐ yes	☐ no

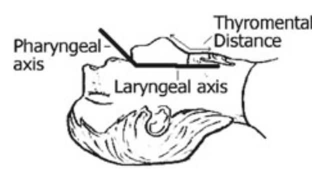
Clinical Examination – LEMON Assessment Method:

L – Look externally for characteristics known to cause difficult laryngoscopy (please circle all that apply)

Face	☐ Small jaw	☐ Edema	☐ Loose Teeth
	☐ Facial hair	☐ Prominent Teeth	☐ Disfiguring of the Jaw
	☐ Difficult Bag/Mask Ventilation (2 person, use of airway, inability to maintain seal)		
Thorax / Abdomen	☐ Pregnancy	☐ Massive ascities	☐ Morbid obesity
	☐ Bowel Obstruction		

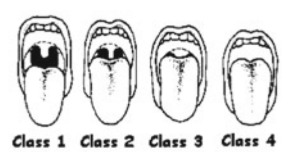
E – Evaluate the 3-3 Rule:

Mouth opening – 3 finger breadths	☐ **yes**	☐ **no**
Thyro-Mental distance – 3 finger breadths	☐ **yes**	☐ **no**



M – Mallampati Score

Mallampati Class:__________



O – Obstruction (Is there any condition that can cause obstruction of the airway which would make laryngoscopy and ventilation difficult?)

- ☐ **Tumors**
- ☐ **Stridor**
- ☐ **Congenital Defects (Down's, Goiter, Pierre-Robin Syndrome)**
- ☐ **Other obvious deformity** ____________________

N – Neck mobility

Can the patient move their jaw forward?	☐ **yes**	☐ **no**
Can the patient fully bend / extend the head and neck?	☐ **yes**	☐ **no**
Is the patient in a cspine collar?	☐ **yes**	☐ **no**

Fig. 1 Our preintubation airway assessment record. These are completed by the respiratory therapist at first patient contact with the ICU team. Note that this includes a modified version of the LEMON airway assessment method [reproduced with permission from Reed et al. [9] and *Emergency Medicine Journal*]

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Post Intubation
Airway Assessment Record

Patient label

Individual Completing Post Intubation Airway Assessment Record: ______________________

Date of Intubation: __________(day)/ __________(mth)/ ________(year)

Level		Specialty	
	☐ PGY (circle) 1 2 3		☐ Internal Medicine
	☐ Attending Physician		☐ Emergency Medicine
	☐ Clinical Associate		☐ Surgery
	☐ ICU Fellow		☐ Anesthesiology
	☐ Respiratory Therapist		☐ Critical Care
	☐ Other		☐ Other

Location of Intubation:

☐ **ICU** ☐ **Pre-hospital (EHS)**
☐ **Ward** ☐ **Other Facility**
☐ **Emergency** ☐ ______________
☐ **OR**

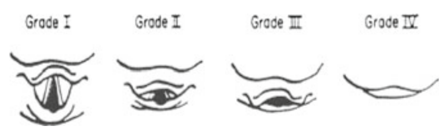
Total Number of Intubation Attempts: ______________
Size of OETT / EVAC placed: ______________
Confirmed Position at the Teeth: ______________
Was Anesthesia called for Assistance? ☐ **YES** ☐ **NO**
☐ **YES – failed attempt** ☐ **YES – anticipated difficult airway**

Modality Utilized for Intubation:

Attempt	Performed by	Successful?		Cricoid?		Technique (circle all appropriate)						
1		Y	N	Y	N	L	GS	B	LW	FOB	LMA	S
2		Y	N	Y	N	L	GS	B	LW	FOB	LMA	S
3		Y	N	Y	N	L	GS	B	LW	FOB	LMA	S

L = laryngoscope B = Bougie GS = Glidescope LW = lightwand
FOB = fiberoptic S= Surgical LMA = laryngeal mask airway

Glottic View during Intubation: ______________



Drug Utilized during Intubation: ☐ **Sedated** ☐ **Awake**

☐ **Midazolam** ☐ **Fentanyl** ☐ **Ketamine** ☐ **Etomidate** ☐ **Succinylcholine**

☐ **Rocuronium** ☐ **Vasopressors** ☐ **Other** ______________________

Date of Tracheostomy:_____**(day)/**______**(mth)/**_______**(year)** **Type of Tube Placed:** ______________

Date of First Change:_____**(day)/**______**(mth)/**_______**(year)** **Surgical Service:** ______________

Comments/ Concerns During Airway Procedures (Intubation or Tracheostomy):

Fig. 2 Our postintubation airway assessment record. These are completed by the respiratory therapist following intubation by the ICU team or by using patient records if the patient was intubated elsewhere

requires reintubation, the airway assessment, prior management, and grade are readily available to the clinician. The postintubation record includes provider characteristics (level and background), location information, medications administered, techniques employed, and Cormack–Lehane grading [11].

Patient Optimization

This step is crucial to the success of ETI. Despite the emergent nature of ETI, there are often a few minutes available to optimize the patient with respect to positioning and cardiopulmonary condition. Insertion of a nasogastric

Table 2 History and physical exam features predictive of difficult mask ventilation and difficult ETI

Mask ventilation	Endotracheal intubation
Snoring or obstructive sleep apnea	History of difficult intubation
Beard	Interincisor distance <3 fingers
Mallampati III or IV	Mallampati III or IV
Age ≥ 55	Decreased neck range of motion
Limited jaw protrusion	Prominent overbite
Thyromental distance <3 fingers	Thyromental distance <3 fingers
Body mass index ≥ 30	
Lack of teeth	
Thick/obese neck anatomy	

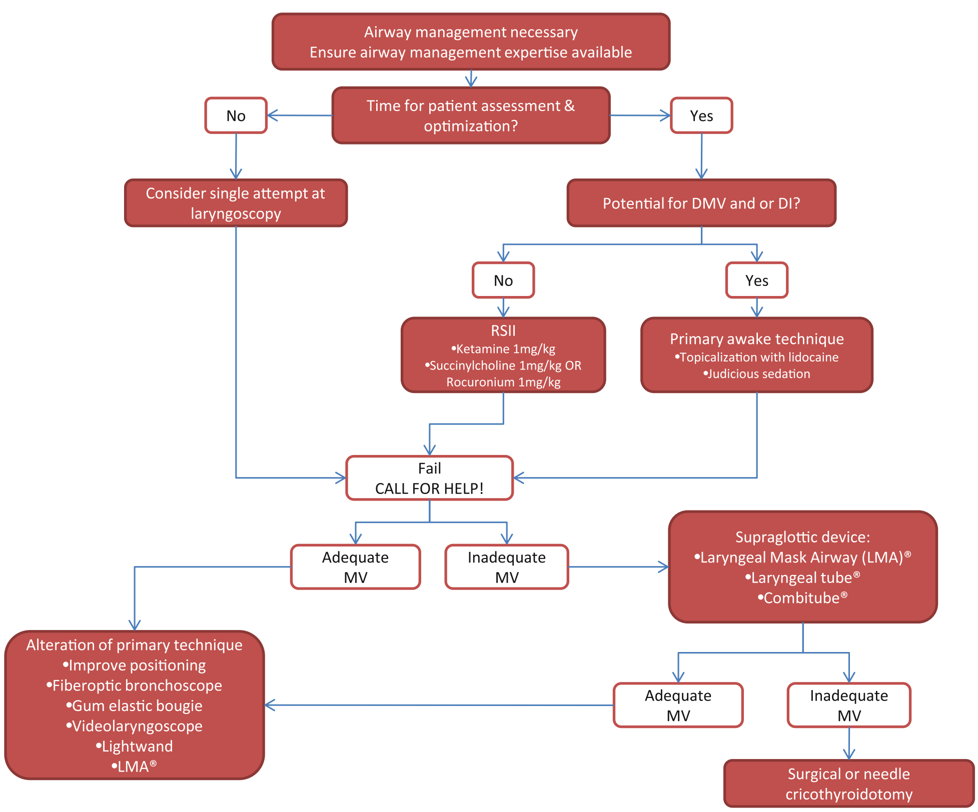
Adapted from [10, 53, 55, 61]

tube should be considered if the patient is at high risk for aspiration (e.g., there is bowel obstruction). If a nasogastric tube is in situ, it should be placed on suction to decompress the stomach. Provided there are no contraindications (e.g., cervical spine instability), the patient should be placed in the sniffing position which facilitates glottic exposure [12]. Preoxygenation can be performed by applying a non-rebreathing face mask with a FiO_2 of 1.0, or by using noninvasive positive-pressure ventilation (NIPPV) [13]. Unfortunately, critically ill patients may be minimally responsive to standard preoxygenation. Mort [5] demonstrated that following 4 min of preoxygenation with an FiO_2 of 1.0 using a tight-fitting mask with assisted ventilation, the mean PaO_2 increased by 37–104 mmHg, with 36% of patients having less than a 5% change from baseline. Thus, it is not surprising that severe hypoxemia (O_2 saturation <80%) around the time of intubation is common, occurring in 19–26% of critically ill patients [1, 2]. However, NIPPV may be more effective than standard preoxygenation. Baillard et al. [13] randomized hypoxemic critically ill patients requiring intubation to preoxygenation using a non-rebreather mask (control group) or to pressure support ventilation through a face mask (NIPPV). Not only did the NIPPV group have higher SpO_2 values prior to intubation, but this benefit persisted during and 5 min following the procedure. Hypotension is also common, with up to 30% of patients having an episode of severe cardiovascular collapse [1, 14, 15]. Adequate IV access is required prior to proceeding and insertion of an arterial line should be considered if time permits. Intravascular volume expansion with isotonic crystalloid solutions and immediate access to vasopressors should be considered in most patients as they may help attenuate the hemodynamic instability around the time of ETI.

Algorithm Approach

There are several published airway algorithms to help clinicians with airway management [8, 16, 17]. Although the

Fig. 3 Airway management algorithm for critically ill patients. *RSII* rapid sequence induction and intubation; *MV* mask ventilation; *LMA* laryngeal mask airway. Note that the medications and doses are suggestions only and are not applicable for every situation. Medication choices and doses need to be individualized for the specific patient and clinical scenario



ASA difficult airway algorithm is an excellent resource, it is designed for anesthesiologists in the operating theater and can be cumbersome [8]. For example, if the airway cannot be secured after multiple attempts, the ASA difficult airway algorithm recommends the anesthesiologist should "awaken the patient" and consider repreparation of the patient for an awake intubation or cancel surgery. However, this is not feasible in critically ill patients in a failed airway scenario. Furthermore, the ASA difficult airway algorithm does not address patient optimization, an essential step in critically ill patients. An algorithm for airway management in critically ill patients is presented in Fig. 3. Depending on the situation, noninvasive management may be required, including the oral or nasal airway and support with mask ventilation. The first step is to determine how much time is available for patient assessment and optimization. If the patient is agonal or pulseless, a single attempt at laryngoscopy may be considered. Fortunately, there usually is time to perform a history and physical examination. Based on the perceived difficulty of ETI and mask ventilation, there are two basic approaches to securing the airway: (1) the "awake" technique with maintenance of spontaneous ventilation or (2) the "Rapid Sequence Induction and Intubation (RSII)" technique with abolition of spontaneous ventilation. However, because of the high risk of difficult intubation, the clinician always needs to be prepared for the unanticipated difficult airway by ensuring appropriate personnel and equipment are immediately available.

Awake Intubation

Although the term "awake" is used, the primary goal of this technique is to maintain spontaneous ventilation during ETI. Although the fiber-optic bronchoscope is almost always used for this technique in the operating room, any modality can be used (e.g., direct laryngoscopy, video laryngoscopy, light wand). As with all ETIs, it is imperative that the practitioner is facile with this technique. If not performed properly, an awake technique can be associated with aspiration, hemodynamic instability, patient agitation, airway trauma, multiple attempts, or failed airway. Critical steps to this technique include:

1. *Patient communication and preparation*. Prior to proceeding, we explain each step to the patient. In our experience, a cooperative and understanding patient greatly facilitates this procedure. In addition, giving glycopyrrolate 0.4 mg IV (an antimuscarinic) will help reduce oral secretions which may improve visualization during bronchoscopy.
2. *Topicalization with local anesthesia*. Topicalization can be performed using nebulization, atomization, or direct application with lidocaine 2%. It is important to remain under the recommended total dose of 5 mg/kg, although a recent article suggested that even at higher doses, toxic plasma concentrations were not achieved [18]. In our practice we often administer a nebulizer containing lidocaine while the patient and equipment are being prepared. Using an atomizer, we then apply 10–15 ml of 2% lidocaine topically to the oropharynx. Topicalization of the posterior pharynx can be facilitated by having the patient protrude the tongue which can be gently retracted using a 4 × 4-in. gauze. Anesthesia below the cords can be obtained by having the patient take deep breaths while atomizing lidocaine in the posterior pharynx. In addition, we often supplement with bilateral topical glossopharyngeal nerve blocks. This is easily accomplished by applying pledgets soaked with viscous lidocaine to the posterior tonsillar pillars for 30 s. This will completely anesthetize the pharynx, the posterior one third of the tongue, and epiglottis. If using a bronchoscope, 2 ml of lidocaine is injected with air through the working port of the bronchoscope to provide anesthesia to the subglottic structures.
3. *Judicious patient sedation*. Critically ill patients are extremely sensitive to any sedative medication. These can easily result in apnea or hemodynamic instability, even in small doses. Provided the patient is well informed, coupled with excellent topicalization, awake intubations can be performed with little or no sedation. If sedation is required, then dosing must be judicious: midazolam 0.5 mg IV or ketamine 10–20 mg IV at a time.
4. *Establish a backup plan*. This can vary depending on the clinical scenario. It may be adjuvant airway tools including a direct laryngoscope or video laryngoscope. However, if the airway is nearly obstructed and extremely tenuous, the alternate plan may be a surgeon on standby to perform a tracheostomy.

Rapid Sequence Induction and Intubation

The majority of critically ill patients should be considered to have a full stomach and are thus at risk for vomiting and aspiration. The period of highest risk for aspiration is between the administration of sedative medications and cuff inflation after a successful ETI. The goal of RSII is to minimize this time at risk. There is indirect evidence that in critically ill patients the proportion of intubations performed by RSII is inversely related to the proportion of difficult intubations, although it is unclear if this is cause or effect [19]. One of the earliest descriptions of RSII advocated a predetermined dose of an induction agent (thiopental 150 mg/70 kg) followed immediately by succinylcholine (100 mg/70 kg) [20]. Although using this approach may shorten the time required for RSII, it certainly may lead to relative anesthetic over- or underdosing, which in turn can result in cardiovascular collapse or awareness, respectively. These risks are likely magnified in critically ill patients. As such, we favor a quickly titrated induction. There are many different approaches and ongoing controversies in RSII and an excellent review is presented by El-Orbany and Connolly [21].

Medications Used in RSII

As a rule of thumb, the dose of hypnotic agents can be reduced by 30–50% in ICU patients with hemodynamic instability. Furthermore, the use of neuromuscular blocking agents (NMBAs) allows a reduced dose of hypnotic agents to be used, thus minimizing their significant hemodynamic side effects. Given the potential hemodynamic instability of critically ill patients, we generally restrict our induction medications to a short-acting benzodiazepine (e.g., midazolam 0.5–2 mg IV) and a hypnotic agent (e.g., ketamine 0.5–1.5 mg/kg IV). Etomidate also has a reasonable hemodynamic profile; however, we generally avoid it given the concerns of adrenal suppression [22] and safety in patients with septic shock [23]. Given these concerns, the use of ketamine is enjoying a resurgence as an induction agent for hemodynamically unstable patients [24]. Ketamine may increase the cerebral metabolic rate of oxygen ($CMRO_2$), cerebral perfusion pressure (CPP), and intracranial pressure (ICP) [25]. However, more recent evidence suggests that ketamine, while maintaining CPP, has no appreciable effect on ICP [26]. Thus, although ketamine has traditionally been avoided as an induction agent in patients with traumatic brain injury (TBI), it may in fact be the ideal hypnotic agent in this population. We avoid propofol as an induction agent due to its significant negative inotropic and peripheral vasodilatation effects. When compared to etomidate and thiopental, propofol is associated with increased risk of hypotension with induction [27].

Neuromuscular blocking agents are used during RSII to help prevent retching and to provide a better view of the glottis. NMBAs should be used only if the clinician is confident that he/she can (1) intubate the airway and (2) mask ventilate in case of intubation failure. If unsure, the airway should be secured through an “awake” or spontaneously breathing technique. There are essentially two NMBAs available for RSII in the critically ill patient: succinylcholine and rocuronium. Succinylcholine is a depolarizing muscle relaxant that provides excellent intubating conditions in 60s at a dose of 1–1.5 mg/kg. However, succinylcholine is contraindicated in patients with malignant hyperthermia, hyperkalemia (serum potassium $\geq$5.0 mEq/l), burns, stroke, spinal cord injury, multiple sclerosis, Guillain-Barre syndrome, degenerative or dystrophic muscular diseases, and prolonged immobilization [28]. Rocuronium is a nondepolarizing NMBA that can be used when succinylcholine is contraindicated. While the evidence comparing succinylcholine to rocuronium is conflicting, succinylcholine appears to provide better intubating conditions compared to rocuronium [29, 30]. If required, rocuronium at a dose of 1.0 mg/kg appears to provide acceptable intubating conditions by 60s [31, 32].

Finally, depending on the clinical circumstances, many RSII algorithms advocate pretreatment with either lidocaine or an opioid (e.g., fentanyl) 3 min prior to pharmacologic paralysis [33]. Although evidence is lacking, lidocaine and fentanyl are thought to attenuate the rise in intracranial pressure with laryngoscopy. Thus, they are often used in pretreatment for RSII in patients with TBI. However, these agents can also cause hypotension [34] which itself is associated with worse outcomes in TBI [35, 36]. Because this strategy increases complexity and is without obvious clinical benefit, we generally avoid pretreatment in RSII in critically ill patients. However, there are certainly circumstances where the clinician may feel their use is justified, e.g., in patients who are severely hypertensive and with tachycardia where exacerbation of these hemodynamics could be detrimental (e.g. cocaine intoxication, acute myocardial ischemia or pheochromocytoma).

Controversies in RSII: Cricoid Pressure and Mask Ventilation

Classically, mask ventilation is not performed during RSII because theoretically it may increase the risk of aspiration through insufflation of the stomach. If patients can maintain oxygenation during the apneic period, then mask ventilation should be avoided. However, there are occasional situations where gentle mask ventilation may be necessary, e.g., the patient who would likely develop life-threatening hypoxemia during the interval from medication administration to intubation. Profound hypoxemia may occur more commonly after a failed attempt at intubation while the backup plan is being instituted. If mask ventilation is required, we always use an oropharyngeal airway to minimize the risk of stomach insufflation. Cricoid pressure is administered to occlude the upper esophageal sphincter and thus reduce the risk of passive regurgitation and subsequent aspiration around the time of RSII. However, the risks and benefits of cricoid pressure in RSII are currently being debated in the literature. Proponents believe it reduces the risk of aspiration. Critics argue that cricoid pressure worsens glottic view, impairs mask ventilation, and increases the risk of aspiration by inducing vomiting and retching [21]. A reasonable compromise may be to apply cricoid pressure, but be prepared to reduce or eliminate it if it impairs either mask ventilation or ETI.

Failed or Unanticipated Difficult Airway

The failed or unanticipated difficult airway is an *immediate*, *life-threatening emergency*. In this case it is prudent to call for help from a provider expert in airway management. Although this situation can often be avoided through careful patient assessment, triage, and preparation, occasionally clinicians will find themselves in this uncomfortable situation. This reflects not only the poor discriminative abilities of the airway physical exam, but also the limited physiologic reserve of the critically ill patient. Initial rescue attempts should focus on mask ventilation using an adjuncts such as the oral or nasal airway. Due to airway collapse and derecruitment, severe hypoxemia that is relatively resistant to mask ventilation may develop. Two-person mask ventilation may help. Adequate mask ventilation should be confirmed by visualization of a rising chest, auscultation, stable oxygenation, and presence of end-tidal CO_2 on capnography. If mask ventilation is adequate, then an alternate strategy for securing the airway may be attempted. It is important that the clinician troubleshoot the causative factors leading to the initial intubation failure so that these may be avoided in subsequent attempts. For example, patient positioning may have been inadequate, so repositioning should occur prior to subsequent attempts at intubation. If mask ventilation is inadequate, then a supraglottic airway device (e.g., laryngeal mask airway) should be inserted to establish an airway. If ventilation is successful, the supraglottic airway device should be left in place until a new plan can be established. This may include intubating through the supraglottic airway or a surgical airway. If at all possible, these more advanced techniques should be performed by an expert in airway management.

Intubation Techniques and Adjuncts

Many alternate methods are available for use as either the primary approach to ETI or as a rescue technique for a failed or difficult intubation. Although each option has advantages depending on the clinical situation, all require previous training and experience and thus should not be attempted for the first time in an emergency situation.

The gum-elastic bougie is a 60-cm endotracheal tube introducer whose tip is at a 35° angle. The bougie is placed in the trachea and then an endotracheal tube is placed over the top of the bougie which guides the tube into the trachea. Keeping the laryngoscope in place while the endotracheal tube is advanced over top of the bougie will facilitate successful intubation. The bougie is useful in situations where there is poor glottic visualization (e.g., Cormack–Lehane grade III or IV) or a small glottic aperture (e.g., presence of swelling or a mass). Confirmation of endotracheal placement can be achieved by feeling the tracheal rings as the bougie makes contact inside the trachea, and by a definitive end point when the mainstem bronchus is entered. In contrast, if the bougie is in the esophagus, the bougie can be freely advanced without an end point and the tracheal rings will not be felt.

Fiber-optic bronchoscopy is a commonly utilized technique for awake intubations. This technique is much easier in a spontaneously ventilating patient than in a deeply sedated or paralyzed patient as it maintains airway patency with improved glottic visualization. Following patient preparation, which includes airway topicalization and the judicious use of sedatives, the bronchoscope is guided through the nasal or oral pharynx until the glottis is visualized, and then it is passed behind the epiglottis and through the vocal cords into the trachea. Once the carina is visualized, the endotracheal tube (which has been preloaded on the bronchoscope) is passed over the fiber-optic bronchoscope, and positioned with the tip 2 cm proximal to the carina.

Video laryngoscopes (e.g., GlideScope®, McGrath®, and Pentax-AWS®) are indirect, rigid, fiber-optic laryngoscopes with a video camera mounted at the end of an angled blade. The images are displayed on a separate video screen. The blade is inserted into the mouth in the midline and guided down the back of the tongue until the glottis is visualized. A styleted endotracheal tube, which has been bent to a similar angle of the video laryngoscope blade itself, is then inserted into the mouth and follows a similar path as the blade. The tip of the endotracheal tube can then be visualized on the video screen and is positioned to enter the glottic inlet. Once this occurs, the stylet is removed and the tube advanced through into the trachea. Unfortunately, the improved view with video laryngoscopy has not consistently translated into increased success at intubation when compared to direct laryngoscopy [37–39]. However, the majority of studies were conducted by experienced intubating physicians with low rates of intubation failure, thus blunting any potential benefit to video laryngoscopy. One study using inexperienced trainees as operators demonstrated that the GlideScope® (Verathon, Bothell, WA) was associated with increased success compared to direct laryngoscopy (93 vs. 51%) [37]. One common difficulty encountered with the GlideScope is passing the endotracheal tube through the glottis despite an adequate view. This can often be facilitated by a *counterclockwise* twist as the tube is advanced through the glottic aperture.

Laryngeal Mask Airway (LMA™, LMA North America, Inc., San Diego, CA) is a supraglottic device that provides a conduit for ventilation. There are several different styles of LMAs, including the LMA Classic™, Proseal™, and Fastrach™ (intubating LMA). Although often used in the elective operative setting, the LMA is also a key rescue device for a failed airway [8]. There are many different techniques described for LMA insertion. However, it is generally inserted while deflated, and facilitated with a jaw-lift. The index finger of the dominant hand is placed at the base of the laryngeal mask (where it meets the tube) and inserted into the patient's mouth behind the tongue and down into the hypopharynx. Upward pressure with the index finger on the hard palate during insertion helps prevent the tip of the LMA from folding. An advantage of the LMA over ETI is its easier insertion, even in the hands of inexperienced providers [40, 41]. However, there are times when an adequate seal cannot be achieved with the LMA. In addition, it does not protect the airway from aspiration and thus its use should be limited to a rescue device in critically ill patients. Finally, the LMA can be used as a conduit for intubation. The Fastrach LMA is designed to accommodate the accompanying Fastrach endotracheal tube. The endotracheal tube is inserted through the Fastrach LMA into the glottis, either blindly or under fiber-optic guidance with an intubating bronchoscope. Multiple techniques for intubation through either a Classic or a Proseal LMA have been described. The simplest method may be to use a fiber-optic bronchoscope to place an Aintree intubating catheter [a modified Cook airway exchange catheter (Cook Medical, Inc., Bloomington, MN) with a larger internal diameter that accepts a fiber-optic bronchoscope] through the LMA and into the glottis [42]. The LMA can then be removed while leaving the Aintree catheter in place. The endotracheal tube may then be guided into the airway over the Aintree catheter. Although there are many alternate supraglottic devices (e.g., Laryngeal Tube™, VBM Medizintechnik GmbH, Sulz, Germany, and Combitube™, Tyco-Kendall, Mansfield, MA), they have not been studied as much as the LMA [43].

Postintubation Management

In the immediate (within 30 min) postintubation period there is a very high risk for complications [1, 2]. Of paramount importance is the confirmation of endotracheal placement because esophageal intubation is a life-threatening emergency. Capnography, although not uniformly used in the ICU setting [44], is the most reliable method to detect esophageal intubation [45]. We feel that capnography should be used to confirm endotracheal placement. The endotracheal tube cuff should be filled with the minimum volume required to provide an adequate seal and the cuff pressure checked frequently. The aim is to prevent unnecessary tracheal ischemia to minimize the risk of postextubation stridor [46]. Given the high prevalence of postintubation hypotension, intravascular fluids and vasopressors should be immediately available to maintain end-organ perfusion. Concurrently, avoiding agitation by implementing short-term sedation allows ongoing resuscitation. Provided that the patient's hemodynamics have been stabilized, a recruitment maneuver (CPAP 40 cmH_2O for 30 s) in the immediate postintubation period has been shown to improve short-term oxygenation [47]. If appropriate, lung-protective ventilation should be instituted to avoid ventilator-induced lung injury [48, 49]. Finally, a portable chest X-ray should be obtained to confirm adequate placement of the endotracheal tube and to assess for potential complications (e.g., pneumothorax, aspiration).

Reducing Complications in ETI

As with any procedure, ETI is a complex interaction between patient, environmental, and practitioner-related factors [8]. Training physicians for ETI, particularly non-anesthesia or emergency medicine personnel, provides a unique challenge in the critical care environment. We have previously shown that more years of training and residency training in anesthesiology was independently associated with a decreased risk of multiple attempts [6], which itself is associated with severe complications around the time of intubation [2]. However, experience in ETI itself may be more important than a specific background (anesthesia vs. nonanesthesia). This is highlighted in the study by Jaber et al. [1], which found that there was no difference in complications between anesthesiologists and nonanesthesiologists. There was also no difference in difficult intubations between the two groups, indicating that all operators (including nonanesthesiologists) were experienced in the procedure. High-fidelity patient simulation shows promise, as experience gained through simulation improves airway management in respiratory arrest scenarios [50–52]. Although it remains unclear whether the skills attained through simulation translate to improved airway management, it may provide a valuable means to improve airway management skills, particularly in less experienced operators. As stated above, newer intubation devices such as video laryngoscopy improve glottic view when

Table 3 Intubation care bundle management adapted with permission from Jaber et al. [48]

Preintubation
Presence of two operators
Fluid loading (isotonic saline 500 ml or starch 250 ml) in absence of cardiogenic pulmonary edema
Preparation of long-term sedation
Preoxygenation for 3 min with NIPPV in case of acute respiratory failure (FiO_2 100%, pressure support ventilation level between 5 and 15 cmH_2O to obtain an expiratory tidal volume between 6 and 8 ml/kg and PEEP of 5 cmH_2O
During intubation
Rapid sequence induction: etomidate 0.2–0.3 mg/kg or ketamine 1.5–3 mg/kg combined with succinylcholine 1–1.5 mg/kg in absence of allergy, hyperkalemia, severe acidosis, acute or chronic neuromuscular disease, burn patient for more than 48 h, and medullar trauma
Sellick maneuver
Postintubation
Immediate confirmation of tube placement by capnography
Norepinephrine if diastolic blood pressure remains <35 mmHg
Initiate long-term sedation
Initial "protective ventilation": tidal volume 6–8 ml/kg of ideal body weight, PEEP <5 cmH_2O, and respiratory rate between 10 and 20 cycles/min, FiO_2 100% for a plateau pressure of <30 cmH_2O

NIPPV noninvasive positive pressure ventilation; *PEEP* positive end expiratory pressure; *FiO_2* inspired oxygen fraction

compared to direct laryngoscopy, but this has not translated into improved success at intubation [37–39].

It is unlikely that a single intervention will dramatically improve the safety of ETI. In contrast, safety in ETI will likely be found in broad, system-based change. For example, Jaber et al. [48] demonstrated that implementation of an ICU intubation bundle was associated with a decrease in life-threatening complications, including severe hypoxemia and cardiovascular collapse. This bundle is presented in Table 3.

Conclusions

Endotracheal intubation in critically ill patients is often a difficult procedure and associated with a high risk of cardiopulmonary instability. Proper patient assessment and optimization is crucial to help mitigate these complications. Based on a focused airway history and physical examination, an algorithmic approach to securing the airway, via an "awake" or a RSII technique, will help the clinician appropriately triage resources and hopefully minimize the risk of a difficult or failed intubation. Nonetheless, with the limitations of airway assessment, the clinician must always be prepared for the unanticipated difficult airway. In addition, airway adjuncts such as the gum elastic bougie or video laryngoscopy may be useful as either primary or rescue techniques, depending on the clinical scenario. Finally, implementation of an ICU intubation bundle may reduce the severe life-threatening complications associated with ETI in critically ill patients.

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