REVIEW

Emergent airway management of the critically ill patient: current opinion in critical care

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Purpose of review
To describe techniques to facilitate safe intubation in critically ill patients.

Recent findings
Despite advances in the treatment of critically ill patients, endotracheal intubation remains a high-risk procedure associated with complications that can lead to appreciable morbidity and mortality. In addition to the usual anatomical factors that can predict a difficult intubation, incorporating pathophysiological considerations and crisis resource management may enhance safety and mitigate risk. Enhancing preoxygenation with high-flow oxygen or noninvasive ventilation, the early use of intravenous fluids and/or vasopressors to prevent hypotension and videolaryngoscopy for first pass success are all promising additions to airway management.
Facilitating intubation by either sedation with paralysis or allowing patients to continue to breathe spontaneously are reasonable options for airway management. These approaches have potential advantages and disadvantages.

Summary
Recognizing the unique challenges of endotracheal intubation in critically ill patients is paramount in limiting further deterioration during this high-risk procedure. A safe approach to intubation focuses on recognizing risk factors that predict challenges in achieving an optimal view of the glottis, maintaining optimal oxygenation, and minimizing the risks and benefits of sedation/induction strategies that are meant to facilitate intubation and avoid clinical deterioration.

Keywords
airway management, anesthesia, difficult airway, preoxygenation, rapid sequence intubation

INTRODUCTION

Airway management of the critically ill patient outside of the operating room is a high-risk procedure. Predicated on urgency and reduced physiological reserve, endotracheal intubation (ETI) is associated with increased risk of hypoxemia, hypotension, dysrhythmias, cardiac arrest, and death [1,2,3▪▪]. Given the high-risk nature of ETI in the critically ill, guidelines were recently published, offering guidance to clinicians [3▪▪,4▪]. This review will highlight both evidenced-based and practical approaches to maximizing safety and optimizing success in ETI of the critically ill patient.

WHAT MAKES INTUBATING THE CRITICALLY ILL PATIENT A CHALLENGE?

Due to airway anatomic factors, the pathophysiology of critical illness, and crisis resource management issues, ETI in the critically ill patient poses unique challenges to clinicians. Table 1 outlines these factors with some suggested maneuvers and rationale.

ANTICIPATING A DIFFICULT ANATOMIC INTUBATION

The anatomical features that predict a difficult ETI were recently summarized in the *Journal of the American Medical Association's Rational Clinical Exam Series* [5▪]. Although this analysis of over 30 000 patients was restricted to operating room ETIs, the data are still useful for clinicians who are assessing the risk of

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KEY POINTS

- Endotracheal intubation is a high-risk procedure in critically ill patients.
- Recognizing, which patients are at higher risk is essential to avoid complications.
- Physiological optimization of the patient is key prior to airway management. This may include the use of high-flow nasal oxygen, noninvasive positive pressure ventilation, and hemodynamic support with intravenous fluids and/or vasopressors.
- An induction of anesthesia with the use of paralysis has never been tested head-to-head with a spontaneously ventilating technique in critically ill patients. Both approaches have their advantages and disadvantages.

anatomic difficulty in critically ill patients. The physical examination findings that best predicted a difficult ETI included the inability to bite the upper lip with the lower incisors (positive likelihood ratio of 14), a short hyomental distance (positive likelihood ratio of 6.4), and retrognathia (positive likelihood ratio of 6.0), whereas the widely used modified Mallampati was less predictive (positive likelihood ratio of 4.1) [5▪]. Data with blinded assessors in critically ill patients are not available. One large study in critically ill patients incorporates the following patient and operator factors: Mallampati score III or IV, apnea syndrome (obstructive), cervical spine limitation, opening mouth less than 3 cm, coma, hypoxaemia, anaesthetist nontrained [6]. Scores range from 0 (low rates of difficult ETI) to 12 (high rates of difficult ETI). Using a cut-off at least 3 was 73% sensitive and 89% specific in predicting difficult ETI.

THE PHYSIOLOGICALLY DIFFICULT AIRWAY

All ETIs in critically ill patients should be considered physiologically difficult [7]. The factors that make it so include the patient's medical history and medications, the hemodynamic stability of the patient based on their shock state, drugs used to induce anesthesia, reason for ETI, sub-optimal patient positioning as compared with operative settings, and intrathoracic positive pressure related to mechanical ventilation [8]. Anticipating how these physiological perturbations will affect the ETI procedure is imperative and patients should be optimized whenever possible before airway instrumentation (Table 1). The use of fluid loading and early use of vasopressor therapy for hemodynamic optimization as part of an 'intubation bundle' has been shown to reduce cardiovascular instability in the periintubation period [9] and should be considered part of routine practice.

PATIENT POSITIONING

The theoretical benefits of proper positioning aim to optimize both anatomic and physiological parameters. The 'sniffing' or ramped-position should more appropriately align the oropharyngeal–laryngeal

Table 1. Unique considerations for intubation of the critically ill

	Maneuver	Rationale
Airway	Preoxygenation with NIV and periintubation oxygenation with high-flow nasal cannula	Optimize FRC, mitigate risk of desaturation
	Maintain spontaneous ventilation	Prevents apnea, minimizes use of hypotension-inducing medications, prevents 'can't intubate, can't ventilate scenario', avoid impairing minute ventilation to compensate for acidemia
	Orolaryngopharyngeal topicalization	Optimizes tolerance of awake video or direct laryngoscopy
	Maintain patients in the upright seated position	Reduces aspiration risk, prevents reduction in FRC
Hemodynamic	Use of vasopressors before intubation	Prevent periintubation and postintubation hypotension induced by medications, positive-pressure ventilation
	Fluid bolus	Mitigate risk of vasoplegia, hypovolemia, high insensible losses from tachypnea
	Cautious use of sedative agents	Recommend significant dose reduction in critically ill and slow titration allowing for medications to take effect before further boluses
Crisis resource	Assigned team members	Clear roles for hemodynamic monitoring, titration of medications, assistance with airway management
	Back up-airway plans put in place before first intubation attempt	Prevention of persistent failed attempts and allows for prompt use of rescue techniques

Some suggested considerations for critically ill patient intubations. Note these differ from conventional elective airway management in the operating room. FRC, functional residual capacity; NIV, noninvasive ventilation.

FIGURE 1. The upright/semiseated intubation. For an upright or semiseated intubation, the airway operator will usually stand to the side of the patient (a) or behind the patient at the back of the bed (b). *Author M.C.S. gave permission for the use of his face in the images.

axes, making glottic visualization and ETI easier compared with a completely flattened patient. Intubating the patient on an incline should also reduce the risk of pulmonary aspiration of gastric contents and of desaturation by maintaining the patient's functional residual capacity [10▪].

A recent multicenter trial of ramped vs. sniffing position for critically ill patients undergoing ETI [11] found that the ramped position was associated with suboptimal laryngeal visualization, but showed no difference in desaturation events during ETI. The ramped positioning may have been suboptimal in this trial and is a consideration when interpreting the results [12].

Some airway operators advocate for an upright or semi-seated position for ETI as this would maximally align the glottic axes. There is retrospective data supporting this approach for first-pass ETI success [13] but randomized clinical trials are lacking. Though unconventional, airway operators stand beside the patient, or on the back of the patient's bed (Fig. 1).

PREOXYGENATION AND APNEIC OXYGENATION

Preoxygenation refers to the delivery of oxygen before the induction of anesthesia, whereas apneic oxygenation refers to oxygen applied to a patient who is not breathing spontaneously.

The concepts and modalities of oxygenation administration around the time of ETI are evolving, especially with the widespread use of high-flow nasal oxygen (HFNO). Oxygen delivery can be achieved using a simple face mask, standard or HFNO cannula, a noninvasive ventilation (NIV) mask, or a combination of these devices. In addition to oxygenation, HFNO generates positive end-expiratory pressure [14,15] and potentially mitigates the risk of patient self-inflicted lung injury [16]. NIV principally works to improve both oxygenation through the delivery of positive end expiratory pressure and ventilation by augmenting minute ventilation with pressure-supported breaths and decreasing right ventricular preload and left ventricular afterload [17].

For apneic oxygenation in a general medical–surgical ICU population, the application of nasal cannula at 15 l/min did not increase the lowest oxygen saturation during ETI attempts [18]. Given the flow-dependent physiological benefits of HFNO [15], it is possible that higher flow rates (i.e. 60 l/min) could improve oxygenation during high- risk ETI.

A recent study compared preoxygenation strategies with HFNO at 60 l/min to NIV in acute hypoxemic respiratory failure patients [19■■]. There was no difference in the primary outcome of preventing hypoxemia during the ETI procedure in all patients. However, in prespecified groups of patients with moderate-to-severe hypoxemia, there were fewer episodes of hypoxemia during ETI when NIV was used (compared with HFNO) [19■■].

A recent single-center trial compared preoxygenation of ICU patients for ETI primarily with hypoxemic respiratory failure using either NIV or NIV with HFNO [20]. In this small trial ($n = 49$), the NIV with HFNO group had statistically significant, though not necessarily clinically significant, differences in oxygen saturation nadir compared with the NIV alone group [100 (95–100) vs. 96 (92–99)%, $P = 0.029$].

It seems reasonable to use either HFNO, or NIV, or a combination of the two to optimize oxygenation during ETI. A rational strategy in moderate-to-severe hypoxemic patients can use NIV for preoxygenation and HFNO for apneic oxygenation. If general anesthesia and apnea is induced, the use of bag-mask ventilation (compared with none) was shown to prevent hypoxemia and not increase the risk of aspiration during ETI in a recent trial of 400 critically ill patients [21■■]. Approximately 11% of patients in the bag-mask ventilation group had severe hypoxemia, as compared with 23% of patients in the apnea group (relative risk, 0.48; 95% CI 0.30–0.77).

THE INDUCTION

It must be remembered that acute critical illness can dramatically reduce general anesthesia requirements [22]. The use of sedation and analgesia to facilitate ETI can increase the risk of hemodynamic and respiratory decompensation in critically ill patients. Sedatives and analgesics can induce sympatholysis and exacerbate cardiovascular dysfunction. In addition, reducing a patient's minute ventilation may blunt a patient's respiratory compensation for metabolic acidosis, potentially exacerbating acidosis and shock. Finally, the indication for ETI is often failure of oxygenation, making preoxygenation difficult [1]. Hypoxemia at the time of induction is a strong risk factor for hypoxemia during ETI [23■], which can be exacerbated by the loss of a respiratory compensation.

There are several intravenous anesthetic agents to choose from, each with unique advantages and disadvantages (Table 2). Any of the agents considered for use in a rapid-sequence intubation can worsen hypotension and dose adjustments, or administering these agents in lower but more frequent doses should be considered to avoid cardiovascular collapse [24–26]. As stated earlier, vasopressors should be considered to avoid hypotension secondary to loss of sympathetic tone and positive pressure [9].

PARALYSIS OR MAINTENANCE OF SPONTANEOUS VENTILATION?

The use of paralytics as part of a 'modified' rapid sequence induction for ETI in critically ill patients is recommended by recent guidelines [3■■,4■]. Although rapid sequence intubation is commonly used in the critical care setting, high-quality evidence supporting this choice is lacking [27]. The use of paralytics should improve intubating conditions, facemask ventilation, supraglottic airway insertion, abolish upper airway muscle tone including laryngospasm, and optimize chest wall compliance. In a double-blinded trial involving 300 healthy patients undergoing elective procedures, paralytics were associated with lower rates of difficult ETI (1 vs. 12%; $P < 0.05$) and other complications, including rates of arterial hypotension or bradycardia requiring treatment (3 vs. 12%; $P < 0.05$) [28]. In a retrospective study involving ETI in a surgical ICU, the avoidance of paralytics was associated with difficult facemask ventilation and severe oxygen desaturation [29].

In a clinical trial comparing succinylcholine to rocuronium in critically ill patients, investigators found no difference between the two agents with respect to oxygen desaturation, or successful first pass ETI [30]. The time to ETI was shorter in the succinylcholine group, which is likely because the dose of rocuronium chosen was 0.6 mg/kg. A 1.2 mg/kg dose of rocuronium (four times the ED95) shortens the onset time of complete neuromuscular block from 89 to 55 s [31]. Any dose of rocuronium will last considerably longer than succinylcholine and the use of sugammadex for rapid reversal of rocuronium is an option [32]. Importantly, if a 'can't intubate, can't ventilate' situation arises, sugammadex does not reverse the hypoxia, hypercapnia and hypotension that accompanies this feared situation, and should not be considered a way to rescue the 'can't intubate, can't ventilate' scenario. Succinylcholine may precipitate life-threatening hyperkalemia in certain groups of patients (i.e. those with preexisting hyperkalemia or prolonged immobility) that may require ICU admission and can cause vagal stimulation resulting bradycardia [27].

Some airway clinicians induce apnea with induction agents and then administer paralysis after successful confirmation of bag-mask ventilation is confirmed. The timing of administration of rocuronium was recently studied, where elective normal

Table 2. Selected pharmacologic agents that may be useful for intubation, with some advantages, cautions and typical doses

Drug	Advantages	Cautions	Typical doses
Sedative/hypnotics			
Midazolam	Sedating and amnesic effects	Deliriumgenic, suppress respiratory rate	1–2 mg i.v. push
Fentanyl	Analgesic properties	Suppress respiratory rate	12.5–100 μg i.v. push
Propofol	Rapid onset	Can lead to cardiovascular instability, especially in setting of impaired cardiac function	10–100 mg i.v. push
Ketamine	Sedation effects with less effect on respiratory rate and hemodynamics	Deliriumgenic, negative inotropy, and hypotension in patients with high sympathetic drive	25–200 mg iv push
Etomidate	Little effect of hemodynamics	Concerns about adrenal insufficiency	0.3 mg/kg i.v. push
Neuromuscular blockers and antagonists			
Rocuronium	Rapid acting paralysis	Longer half life	0.6 mg/kg i.v. push
Succinylcholine	Immediate paralysis, shorter half life	Can induce hyperkalemia	1–2 mg/kg i.v. push
Sugammadex	Reverses effect of neuromuscular blockade agents	If reparalysis is needed, rocuronium will be ineffective, anaphylaxis, binding of oral contraceptives	16 mg/kg for profound block
Vasopressors/inotropes			
Phenylephrine	Increase systemic vascular resistance	Can cause reflex bradycardia	100–200 μg i.v. push
Norepinephrine	Increase systemic vascular resistance	Not typically used as a push but rather as continuous infusion	Up to 2 μg/kg/min
Vasopressin	Increase systemic vascular resistance, less impact on pulmonary vascular resistance	Pure vasoconstriction with no inotropy	Bolus 1 U i.v. Infusion 0.04 U/min i.v.
Epinephrine	Can be used as both an infusion or as an i.v. bolus Has both alpha (vasoconstriction) and beta effects (inotropy)	Tachyarrythmias and cardiac ischemia, can increase lactate (which may not be clinically significant but can impact lactate clearance as a marker of response to therapy)	Bolus 10–100 μg i.v. push Infusion 0.05–2 μg/kg/minute
Dopamine	Can increase heart rate in patients who are relatively bradycardic and hypotensive Comes premixed so, does not have to be prepared during an emergency	Tachyarrythmias Typically run as an infusion, not as a bolus	2–20 μg/kg/minute

i.v., intravenous.

airway patients in the OR were randomized to receive rocuronium before or after confirmation of mask ventilation [33]. The early rocuronium group resulted in a significantly larger mask tidal volume and earlier ETI than the late administration arm, suggesting that if apnea is chosen – then using paralytics is potentially helpful.

The prototypical spontaneous ventilating ETI approach is the awake fiberoptic ETI. This technique has a high success and safety profile in the operating room and should be considered by clinicians who have experience with this approach in patients who can tolerate it. A recent systematic review and meta-analysis of 37 randomized trials including over 2000 patients, demonstrated less than 1% ETI failures and serious adverse events [34■■].

Applying studies in healthy outpatients to the critically ill is potentially problematic with limited generalizability. For example, somewhat paradoxically, most of the out-of-operating room high-risk ETIs are performed by nonanesthesiologists [27]. In this respect, inducing general anesthesia and using paralytics in ICU patients may be dangerous, especially if securing ETI becomes challenging. In healthy patients, direct laryngoscopy is usually successful with minimal sedation [35]. Therefore, a combination of judicious local anesthetic topicalization and small amounts of sedation may be a more hemodynamically favourable approach to ETI in critically ill patients.

Inducing apnea in critically ill patients can result in rapid desaturation (secondary to loss of functional residual capacity, a component of low-mixed venous oxygenation, high metabolic rate, physiological shunt, and ventilation perfusion mismatch), unlike in healthy patients in the operating room who, when properly preoxygenated can withstand a minute or more of apnea [1]. A prospective trial using small boluses of propofol, proactive use of vasopressors, avoidance of paralytics and maintenance of spontaneous ventilation in 400 critically ill patients was associated with low rates of desaturation (7%), hypotension (4%), and difficult ETI (10%) [36].

Furthermore, maintenance of spontaneous respirations prevents the ‘can’t intubate, can’t ventilate’ scenario and allows time for expert personnel to arrive if ETI is difficult. At present, there are no trials comparing rapid sequence intubation vs. cautious sedation and maintaining spontaneous ventilation.

VIDEO OR DIRECT LARYNGOSCOPY, STYLET OR BOUGIE?

Videolaryngoscopy has become widely available and is an option for both routine and anticipated difficult ETI in both operating room and nonoperating room settings [3▪▪]. The most recent randomized clinical trial in ICU patients comparing video to direct laryngoscopy found no difference in first pass success rates but higher rates of life-threatening complications in the videolaryngoscopy group [37]. This finding may be a result of better glottic visualization but more difficulty in achieving tracheal cannulation [38]. A systematic review of the two techniques across multiple ETI settings not only found videolaryngoscopy has higher success in first pass attempts but also highlighted the importance of proper training with the device and that not all videolaryngoscopes perform equally well [39]. The routine combination approach of a videolaryngoscope and a fiber-optic bronchoscope for a rescue strategy was recently proposed as an effective airway strategy technique, especially for patients with a predicted difficult airway [40]. The use of a bougie as first line can also be considered. A recent single-center trial in an emergency department found higher rates of first-attempt ETI success among all patients whenever compared with a stylet (98 vs. 87%, $P < 0.001$) [41].

SUPRAGLOTTIC AIRWAY RESCUE

Supraglottic airway devices are potential rescue devices as they are relatively easy to insert and re-establish oxygenation, provide some protection against aspiration, and can be used as an intubation conduit [3▪▪]. Whenever available, second-generation supraglottic airway devices are preferred because they have a separate gastric channel to mitigate some risk of aspiration of enteral contents [42]. If successful oxygenation can be achieved with a supraglottic airway device then this should be maintained until expert help arrives [3▪▪].

THE SURGICAL AIRWAY

Avoiding cognitive overload and mitigating the risk of impaired decision-making and performance is paramount during airway crises. After failed ETI attempts and the inability to effectively oxygenate a patient, clinicians should not wait until life-threatening hypoxemia before proceeding to a surgical airway. ‘The Vortex’ [43] is a cognitive aid aimed to prevent repeated attempts at unsuccessful ETI by advocating early call for expert help and transition to a surgical airway [3▪▪].

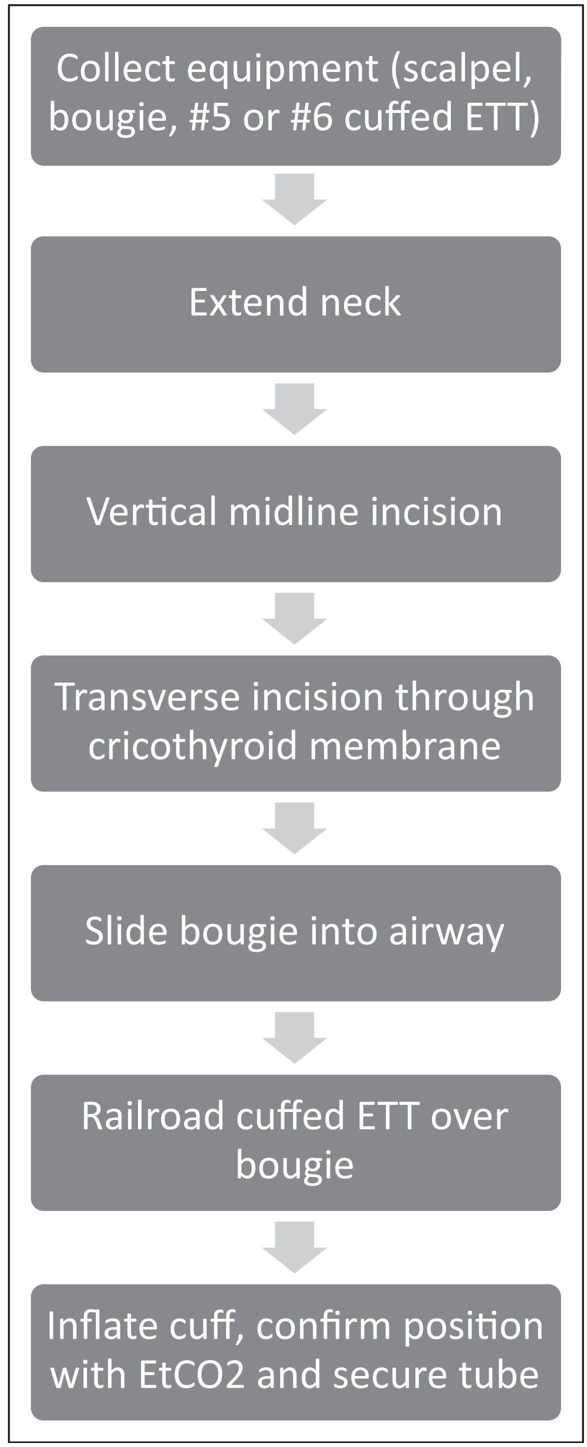

FIGURE 2. The surgical cricothyroidotomy.

The recommended surgical airway is an 'open' cricothyroidotomy via a scalpel-bougie-tube cricothyroidotomy technique [3■■]. Compared with a percutaneous technique, the open technique is faster, more reliable with fewer steps, and has a higher success rate [44]. Simulated practice of surgical airway management should be part of training and maintenance of airway skills for critical care physicians so that when this rare situation occurs, clinicians are familiar with the technique [3■■]. The key steps are outlined in Fig. 2.

CONCLUSION

In addition to the usual airway considerations for ETI in the OR, critically ill patients have other considerations that must be addressed. These include the unique pathophysiology of the presenting critical illness, the limitations of the out-of-operating room environment, the anticipation of periintubation and postintubation hemodynamic and respiratory complications and avoiding cognitive overload to call for help early (as is practiced in routine operating room settings). Best practice evidence continues to evolve with evaluation of airway devices, and sedation and oxygenation strategies to help guide clinicians to safely perform ETI in critically ill patients.

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