Intubation in the Critically Ill: When, How, and How Long?

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KEYWORDS

• Endotracheal intubation • Intubation • Tracheal intubation • Mechanical ventilation
• Acute hypoxemic respiratory failure • Positive pressure ventilation • Extubation
• Spontaneous breathing trial

KEY POINTS

- Intubation is a common procedure and carries significant physiological impact on cardiorespiratory physiology.
- Clinician judgment, objective clinical data, and physiological parameters, remain the cornerstone to decide when to intubate.
- Thresholds for intubation timing are difficult to determine and may vary in each individual indications.
- Hemodynamic optimization, pre-oxygenation/ventilation, technique, medication selection, team preparation, and immediate post-intubation management represent the key elements of this procedure.
- There is no standard strategy to predict a patient's readiness for extubation, but integrated assessment of physiologic reserve and airway safety can assist in the decision.

INTRODUCTION

Endotracheal intubation or insertion of an endotracheal tube (ETT) refers to the placement of a tube in the trachea through the mouth or nose. This is most commonly performed via visualization of the glottic opening, via direct laryngoscopes and video laryngoscopes (VL).[1] Placement of an ETT provides direct and secure access to the airway, allowing ventilatory control within a closed circuit. In modern medicine, endotracheal intubation with initiation of mechanical ventilation (MV) remains a cornerstone of the management of critically ill patients.

The origin of intubation can be traced to the 18th century, when its use was described in drowning victims[2] and neonatal resuscitation by Scheel.[3] Surgical tracheostomy predated intubation as a means of securing access to the central airway,[2] but endotracheal intubation marked a major advance in airway management by allowing tracheal access without the need for an incision. Modern-day intubation technique and tools were shaped in the twentieth century by pioneers like Magill and Chevalier Jackson, while parallel advances in general anesthesia helped refine its practice[4] and later gave rise to concepts such as rapid sequence intubation (RSI).[5]

Although techniques and devices continue to evolve,[6] the most consequential questions in airway management extend beyond the technical act of tube placement. Rather, clinicians are frequently challenged by decisions regarding *when* to intubate, *how* to intubate, and *how long*

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Clin Chest Med 47 (2026) 431–446
https://doi.org/10.1016/j.ccm.2026.04.001

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Abbreviations	
ARDS	acute respiratory distress syndrome
CHEST/ATS	American College of Chest Physicians/American Thoracic Society
CLT	cuff leak test
COPD	chronic obstructive pulmonary disease
CPAP	continuous positive airway pressure
CPF	cough peak flow
DTF	diaphragmatic thickness fraction
ECMO	extracorporeal membrane oxygenation
ED	emergency department
ETT	endotracheal tube
MV	mechanical ventilation
ICU	intensive care unit
LV	left ventricular
NIV	non-invasive ventilation
PEEP	positive end-expiratory pressure
RSBT	rapid shallow breathing index
RSI	rapid sequence intubation
RV	right ventricular
SBT	spontaneous breathing trial
VL	video laryngoscopes

an artificial airway should be maintained. These decisions are inherently complex and shaped by the interaction of physiology, underlying disease, clinician expertise, and the procedural environment, all of which contribute to meaningful variability in practice. In this narrative review, we examine these questions from an evidence-based, physiologically grounded, and patient-centered perspective, with the goal of providing a clinically relevant framework to guide decision-making across the continuum of endotracheal intubation.

SECTION 1: INDICATIONS AND PHYSIOLOGICAL CONSIDERATIONS

Clinical indications for intubation are well established in a qualitative fashion, but there has been historical difficulty determining specific thresholds for individual indications. The decision to proceed with intubation remains clinical and relies on physician judgment (**Table 1**). Factors weighed are related to the patient, environment, and include personal expertise and risk assessment (**Fig. 1**). Organizations, including the Society of Critical Care Medicine, the American College of Emergency Physicians, the Intensive Care Society, and the Difficult Airway Society, have issued guidance on acute airway management. However, these largely focus on technical, procedural, and safety aspects of tracheal intubation, rather than offering an explicit framework for the indications for endotracheal intubation in the critically ill.[7–10]

Multicenter studies provide useful, context-dependent, insight into the most common indications for tracheal intubation in critically ill. The INTUBE study included nearly 3000 patients from 29 different countries who underwent tracheal intubation in the intensive care unit (ICU) and emergency department (ED). More than 50% of them were intubated for respiratory failure (52.3%), followed by neurological impairment (30.5%), cardiovascular instability (9.4%), airway obstruction (4.6%), and urgent procedure or others (3.3%).[11] Another trial comparing the use of direct versus video laryngoscopy showed that among the main indications for intubation were altered mental status (45.3%), acute respiratory failure (30.4%), emergency procedure (15.4%), and cardiac arrest (5.9%).[12]

The peri-intubation period has a profound impact on the cardiorespiratory and neurologic physiology. A key feature of these changes is their rapid and dynamic nature, with varying magnitude and clinical impact (**Fig. 2**). With induction, there are expected hemodynamic changes[7,13] including loss of muscular tone and airway collapse.[14] Preoxygenation maneuvers should saturate the alveoli with oxygen.[15] As the laryngoscope blade is advanced, mechanical stimulation of supraglottic structures—particularly the epiglottis and surrounding pharyngeal tissues—triggers a reflex sympathetic response. Although this response may be attenuated by anesthetic agents, it is often not completely abolished.[16] If preoxygenation was effective, then apneic diffusion oxygenation should occur as the decrease in effective lung volume creates a pressure gradient between the upper airway and the alveoli, hence generating oxygen diffusion in the alveoli.[17] Given loss of effective ventilation, a rise in $PaCO_2$ is expected.[17] As hypercapnia progresses, elevated Pa_{CO_2} can promote pulmonary vasoconstriction, and the effect can be amplified when accompanied by hypoxemia and acidosis.[18,19] Once the ETT is placed and the cuff is inflated, MV can be initiated through a closed respiratory circuit. As MV initiates, positive pressure is applied to deliver a target tidal volume or inspiratory pressure, depending on the selected mode, at a set respiratory rate and inspiratory flow. Positive end-expiratory pressure (PEEP) is also applied to maintain end-expiratory lung volume and reduce alveolar derecruitment. Beyond enabling rapid changes in alveolar ventilation and oxygenation, initiation of positive-pressure ventilation increases alveolar pressure and mean intrathoracic (pleural) pressure. These changes can raise transpulmonary pressure and may increase pulmonary vascular resistance by compressing alveolar vessels—particularly at higher

Table 1
Common clinical indications for endotracheal intubation in critically ill patients

Category	Indication	Clinical Comment
Respiratory failure	Hypoxemic respiratory failure	Consider when oxygenation remains inadequate despite supplemental oxygen or noninvasive support, particularly with worsening distress or fatigue.
	Hypercapnic respiratory failure	Consider when progressive hypercapnia and acidemia reflect ventilatory failure, especially if non-invasive ventilation fails, is contraindicated, or is not tolerated.
Airway protection/ airway patency	Impaired airway protection	Indicated when airway reflexes are impaired or aspiration risk is high.
	Impending or established upper airway obstruction	Consider when edema, bleeding, trauma, or structural disease threatens airway patency.
Neurologic failure	Altered mental status or encephalopathy	Not an absolute indication, but may warrant intubation if airway protection, secretion clearance, or ventilation is compromised.
Trauma	Craniofacial, neck, or airway trauma	Often required when injury, bleeding, or edema may rapidly compromise the airway.
Patient safety/ facilitation of care	Agitation or inability to safely continue essential therapy	May be necessary when severe agitation prevents safe delivery of life-sustaining therapy or essential procedures.
Cardiovascular collapse	Cardiac arrest	Provides a definitive airway for controlled oxygenation and ventilation during resuscitation.
	Profound shock	Not absolute, but often needed when respiratory failure, encephalopathy, or high metabolic demand complicates resuscitation.
Procedural indications	Need for airway control during urgent procedures	May be required to secure the airway during high-risk procedures or when deep sedation is needed.

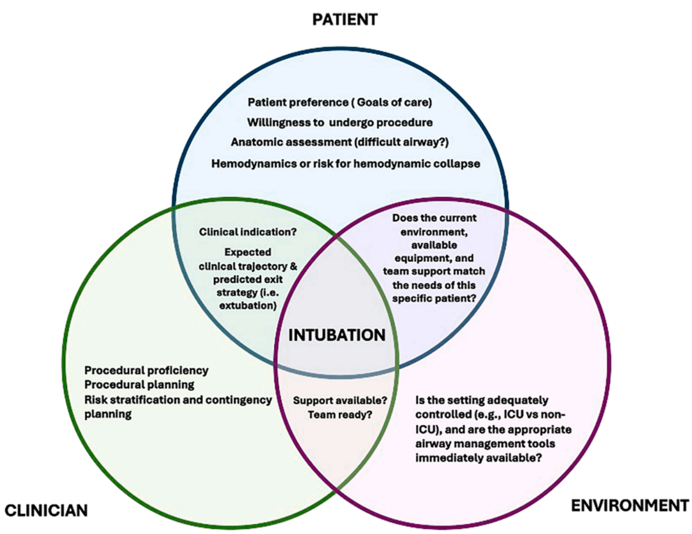

Fig. 1. Patient, clinician, and environmental considerations for intubation.

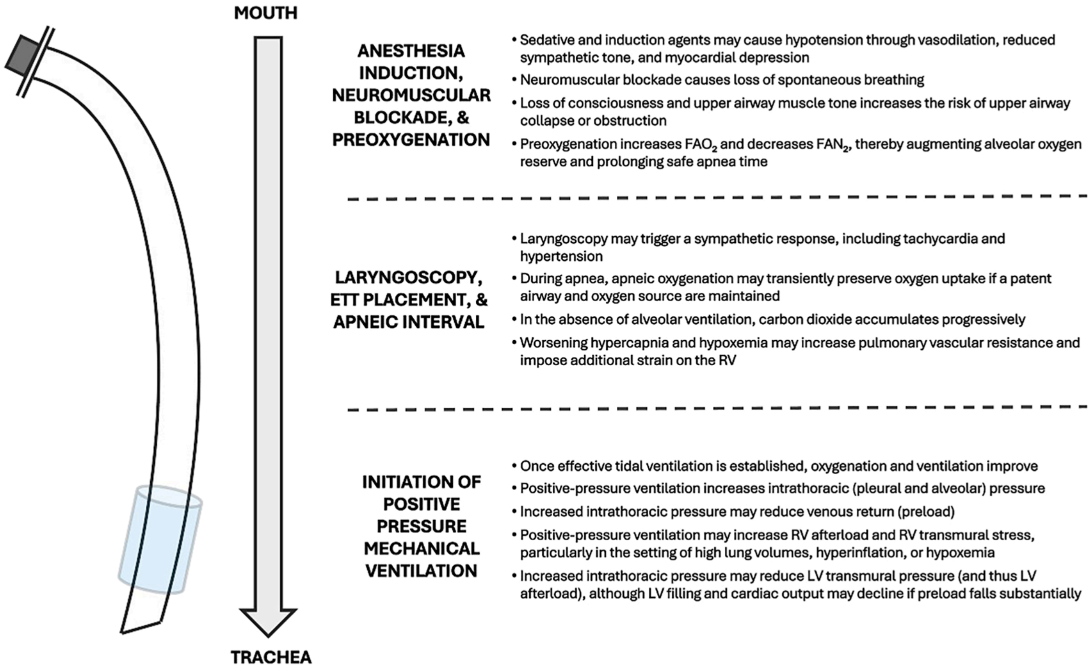

Fig. 2. Physiologic changes during intubation. Fraction of alveolar oxygen (FAO2), Fraction of alveolar nitrogen (FAN2), RV, and LV. LV, left ventricle; RV, right ventricle.

lung volumes—while also increasing right atrial pressure and reducing venous return. Airway pressurization is also transmitted to the abdomen, increasing intra-abdominal pressure, especially in patients with reduced abdominal wall compliance.[20] Such changes in pressures have a net outcome of decreasing bilateral ventricular preload, increasing right ventricular (RV) afterload, and effectively decreasing the left ventricular (LV) afterload.[21,22]

SECTION 2: WHEN TO INTUBATE?

Once a patient requires ETT placement, efforts to optimize noninvasive respiratory support should be made. There are several noninvasive support modalities for patients with respiratory failure, including large bore non-occlusive nasal cannulas (known as high-flow nasal cannula or HFNC), continuous positive airway pressure (CPAP), and Bilevel positive airway pressure, with these last 2 also labeled non-invasive ventilation (NIV) strategies.[23]

Noninvasive respiratory modalities can provide escalating levels of physiologic support. HFNC improves oxygenation primarily by delivering high, stable FiO_2, reducing entrainment, washing out nasopharyngeal dead space, and providing a small amount of end-expiratory pressure; CPAP provides continuous distending pressure to improve alveolar recruitment and reduce work of breathing; and NIV can additionally provide inspiratory pressure support to augment tidal volume and minute ventilation, thereby assisting with hypercapnic ventilatory failure. Evidence supports their use in selected patients with cardiogenic pulmonary edema,[24,25] acute exacerbations of chronic obstructive pulmonary disease (COPD),[26] obesity,[27] and hypoxemic respiratory failure.[28]

While NIV appears attractive to avoid or delay intubation, the question then becomes when to determine its failure? There are recognized risk factors associated with NIV failure including severity of critical illness as measured by scores like SOFA or SAPS II, presence of pneumonia, sepsis,[29,30] and acute respiratory distress syndrome (ARDS), especially the ones with pulmonary etiology.[31] In a secondary analysis of the LUNG SAFE study evaluating respiratory support strategies in ARDS, 2800 patients were initially managed with NIV; NIV failed (requiring subsequent intubation) in 37.5%. Failure was associated with greater severity of illness (SOFA score), worse oxygenation (lower PaO_2/FiO_2), and higher $Paco_2$.[32] In addition, Fratt and colleagues evaluated early predictors for intubation in patients with acute hypoxemic respiratory failure and NIV support and found tidal volumes greater than 9 mL/kg of predicted body weight and PaO_2/FiO_2 less than 200 mm Hg at the first hour were associated with intubation.[33] It is important to distinguish *true physiologic NIV failure* from *NIV intolerance or interface-related failure*. Suboptimal mask fit with excessive leak, poor synchrony, inadequate humidification, pressure intolerance, anxiety/claustrophobia, skin breakdown, or inability to clear secretions can prevent delivery of effective ventilation. These factors may prompt intubation even when the underlying pathology might otherwise be amenable to NIV, and they should be considered separately when interpreting “NIV failure”.

Beyond factors associated with failure, multiple scores have been used to aid in recognizing when non-invasive strategies have been unsuccessful. The ROX index (SpO_2/FiO_2), divided by respiratory rate,[34] showed that an index greater than 4.88 in patients on HFNC for greater than 12 hours was associated with a decreased need for MV (HR 0.273; CI 0.121–0.618). Later, Duan and colleagues demonstrated that the ROX index also had moderate predictive power to predict failure for NIV methods in patients with acute respiratory failure (AUC 0.64–0.77).[35] Another validated tool to predict NIV failure is the HACOR score, which incorporates five variables: Heart rate, Acidosis, Consciousness, Oxygenation, and Respiratory rate. Higher HACOR scores indicate greater risk of NIV failure. A HACOR score greater than 5 at 1 hour of NIV, has a positive predictive value of 87.1%, negative predictive value of 81.6%, and diagnostic accuracy of 83.7% for NIV failure.[36] An updated HACOR score includes presence of pneumonia, cardiogenic pulmonary edema, ARDS, septic shock, immunosuppression, and organ failure as part of the assessment. It better discriminates NIV failure than the original, and provides pragmatic cutoffs: 7, 10.5, and 14 points corresponded to approximately 25%, 50%, and 75% probability of NIV failure, respectively, when assessed early after NIV initiation (typically within 1–2 hours).[37]

Another aspect to consider is if a proactive or reactive approach is preferred (ie, early vs late intubation). There is no formal definition for early or late intubation and literature not only differs among its terminology but also does not show consensus on optimal intubation timing.[38,39] Though there have been specific clinical scenarios, like the early COVID-19 pandemic, in which early intubation was recommended, this was not approached from a ventilatory and gas exchange perspective, but rather to minimize aerosolized particles. 4[40,41] Adding to this, Wanis and colleagues conducted a target trial emulation using the Medical Information Mart for Intensive Care IV database to compare early versus delayed intubation strategies in critically ill patients: early was defined as intubation within 8 hours of ICU admission, whereas delayed referred to intubation after 48 hours. This trial found that a delayed strategy did not increase mortality and avoided intubation in most patients[42]; however, application of this data in the real world is challenging and should be interpreted carefully, as temporal interventions are prone to biases and clinical variables encompassing intubation timing tend to be dynamic and inconsistent.

Practice patterns regarding intubation are variable among physicians and can even vary geographically. A large survey by Yarnell in 2024 showed that among health care staff, the most considered variables to recommend intubation were oxygen saturation, breathing pattern, inspired oxygen fraction, and level of consciousness; nonetheless, the recommendation to intubate deferred between providers and between same regions and countries.[43] Similarly, Bauer and colleagues performed structured interviews with critical care physicians to evaluate factors related to the decision for intubation and found that—aside from gross evidence of distress—there was no consensus among clinicians and the decision to intubate was influenced by clinical trajectory, alignment with patient’s values, clinician experience, and the clinical environment.[44] There is no single universal threshold for *when to intubate*. The decision should be individualized and based on a careful risk–benefit assessment of continuing NIV versus initiating invasive MV, considering the clinical trajectory and the procedural risks. Intubation risks to weigh are mostly related to cardiovascular instability, hypotension or risk for cardiovascular arrest, severe hypoxemia, aspiration and mechanical injury from the ETT (tracheal or bronchial lacerations, pneumothorax)[11] and ventilator associated complications.

Lastly, patient preference and values play an essential role. Anticipatory discussion about timing, intubation approaches, and expected complications while on MV (pain, sedation, immobility, delirium, etc.) should be held in a timely manner. Patients should participate in discussions about reasonable NIV trials, if clinically appropriate, or temporization until resolution of their underlying medical condition. These discussions ensure preservation of patient autonomy and should help reduce potential harm. In qualitative evaluation of patients 1 year after being on MV, 86.5% would still have made the same decision, but pain from the ETT or financial burden of critical illness could have made them change their decision.[45] As such, discussing these beforehand becomes essential.

SECTION 3: HOW TO INTUBATE?

Induction as a Physiologic Stress Test and Decision to Intubate

Tracheal intubation is a high-risk physiologic transition in the critically ill. Roughly 45% of intubations in critically ill patients result in at least one major adverse event, and the higher risk in this population is due to their underlying unstable physiology.[46,47] This originated the concept of the *physiologically* difficult airway.[47] Recent guidelines highlight an association between peri-intubation hypotension and ICU mortality, though optimal management strategies remain poorly defined due to patient complexity and heterogeneity.[7] Intensivists must have an in-depth understanding of the multiple mechanisms leading to physiologic stress during induction and intubation so that they can anticipate, prevent, and manage complications.[48–50]

The first step in intubation is recognizing the optimal physiologic window for intervention. Traditional indications for intubation, though necessary, are insufficient; trajectory outweighs any absolute cutoff.[43,44] Even when intubation appears inevitable, immediate action is often not safest.[38] While risk cannot be eliminated, thoughtful optimization, bridging with NIV when appropriate, and timing are paramount. In some cases, when feasible, avoiding intubation altogether may be the safest strategy.

Pre-intubation and Induction—Failing to Prepare Is Preparing to Fail

Hemodynamic optimization

Hemodynamic optimization in all patients includes careful volume assessment with judicious intravenous fluids if appropriate. In critically ill patients, it is advisable to have vasopressors available and ready for infusion prior to induction. Norepinephrine, or pure vasoconstrictors, like phenylephrine, are generally utilized; however, other vasoactive medications may be appropriate in select cases.[51] Often, vasopressors should be given in anticipation of changes in vascular tone with induction. While prophylactic fluid boluses and vasopressors have not demonstrated improved outcomes in unselected critically ill populations, they are often necessary in patients with specific physiologic vulnerabilities.[7,52] Several high-risk physiologic phenotypes warrant particular attention and preparation prior to intubation (see **Table 2**). Often these states overlap and may lead to deteriorations that cannot be overcome with even the best plan. In the appropriate patient, many of these mixed states may benefit from pre-induction extracorporeal membrane oxygenation (ECMO) consultation.

Pre-oxygenation and ventilation

Recent evidence suggests NIV reduces hypoxemia during intubation as compared with HFNC and facemask oxygen and should be strongly considered.[53] In patients with underlying acidemia, ventilation must be maintained to prevent worsening acidosis and decompensation. Placing patients in the semi-fowler position increases functional residual capacity and may improve pre-oxygenation and safe apnea time similar to supine sniffing position; however, a ramped position may decrease first-pass success.[54]

Intubation approaches

The priorities during induction are, in order: *preservation of life, amnesia, and comfort*. RSI, with an induction agent followed immediately by a neuromuscular blocker and endotracheal intubation, remains the standard approach in most critically ill adults.[7] Cricoid pressure, a traditional component of RSI, has increasingly been questioned.[55] Modified RSI, with positive pressure ventilation provided after induction, has increased in popularity.[9] Alternatively, delayed sequence intubation can be used in patients in which preoxygenation is complicated due to agitation, delirium, and uncooperativeness. This technique involves using a sedative-hypnotic agent, generally ketamine, prior to preoxygenation and paralytic administration.[7,56,57] In patients where spontaneous ventilation must be prioritized or who have an anticipated difficult airway, awake intubation is indicated.[58,59] Many of the technical aspects of intubation are beyond the scope of this article but deserve much consideration. When available, VL appears to provide higher first-pass success and better glottic visualization than direct laryngoscopy.[12,60,61] First-pass success should be prioritized in planning as each additional attempt is consistently associated with severe hypoxemia and cardiac arrest.[11]

Medication selection

Induction agent selection should prioritize hemodynamic stability. Etomidate or ketamine are commonly favored because they better preserve blood pressure than propofol. Propofol can cause significant vasodilation and myocardial depression and should be used cautiously in patients with shock or limited cardiovascular reserve, with dose reduction and vasopressor readiness when chosen.[7,11] While prior studies suggested worse outcomes with the use of etomidate over ketamine, this has been more recently challenged and either medication is appropriate in most patients.[62–64] Pretreatment with lidocaine and fentanyl has largely fallen out of favor, except in select scenarios where sympathetic attenuation is desired (see Table 2).[65] Rocuronium and succinylcholine are both acceptable neuromuscular blockers for RSI and likely improve first-pass success.[66] Rocuronium offers a lower risk of hyperkalemia and malignant hyperthermia with a safer profile in myopathic states. Succinylcholine offers faster offset, allowing earlier neurologic and sedation assessment after intubation and may provide more optimal intubating conditions than rocuronium.[67]

Team and process optimization

Many complications from endotracheal intubation are related to modifiable human and systems factors; as such, process optimization is crucial.[68–70] Prior to an emergent intubation, the team should have a shared mental model through a pre-brief that clearly communicates individual's roles, planned medication management, primary/secondary airway approach, and an overt request for input from the team. Checklists and protocols appear to reduce complication rates.[71] Even a simple mnemonic like Monitors, IV, Suction, Oxygen, Drugs, Airway can quickly identify missing and necessary components for any critically ill intubation. Communication failure contributes to a substantial proportion of sentinel events and should be proactively addressed.[72] An effective technique utilizes the "three C's of communication" with citing an individual by name, giving clear instructions, and ensuring closed-loop communication.[73]

Post-intubation Management

After successful endotracheal intubation, ongoing vigilance is needed to assess and respond to the immediate hemodynamic consequences of the transition to PPV and sedation. Initial ventilator settings should be personalized depending on the patient's illness and comorbidities as described in Table 2.

SECTION 4: HOW LONG TO INTUBATE?

While intubation longer than 7 days is considered prolonged,[96] determining optimal time to extubate remains a challenge. On one hand, premature liberation can lead to extubation failure and increase mortality risk. According to the Weaning according to a New Definition study, mortality rate almost triples (6% to 17%) in patients who failed within 24 hours of the first liberation attempt.[96] On the other hand, the longer a patient remains intubated, greater the risk of extubation failure,[97] reflecting cumulative effects of prolonged MV and sedation exposure. Delayed liberation increases the risk of ventilator-related pneumonia, laryngotracheal injury, critical-illness myopathy, and increased costs related to prolonged hospitalization among others.[98,99] The dynamic nature of a disease state warrants readiness as soon as the inciting event that led to respiratory failure starts to improve. This requires applying evidence-based tools to evaluate readiness (including spontaneous breathing trials, SBT, and airway protection assessment), and providing targeted post-extubation support (eg, HFNC or NIV) for patients at high risk of failure.

Determining Readiness to Extubate

Extubation failure occurs in 10% to 20% of patients who pass a weaning test.[99,100] In a multicenter retrospective study involving 184,705 patients across 75 ICUs, reintubation was associated with 32% increase in mortality, and the risk was highest in patients reintubated in the first 72 to 96 hours.[97] Common risk factors for failed extubation include age, duration of MV, chronic cardiac condition, and chronic respiratory condition. To predict extubation success, tools and calculators such as ExPreS and POSE are available.[96,101] These tools incorporate both physiologic and patient-specific variables to aid clinicians in decision making.[101] However, they are neither widely validated nor uniformly implemented in clinical practice. The decision to extubate is mainly governed by the provider's best clinical judgment.

Screening for patient readiness

The 2017 official American College of Chest Physicians/American Thoracic Society (CHEST/ATS) practice guidelines recommend protocolized reduction of sedation in patients ventilated for more than 24 hours.[102] Sedation can severely impact effective neurologic assessment and contribute to ICU-acquired delirium.[100] Daily spontaneous awakening trial can allow evaluation of patient's cognitive status. While a Glasgow Coma Scale is a helpful tool to evaluate the consciousness of a patient requiring MV for hypoxemic and hypercapnic respiratory failure, the same can be misleading in patients with acute brain injury.[100] According to a target trial emulation that included 1406 patients with acute brain injury across 8 ICUs in Toronto, prompt extubation after passing weaning trial was associated with more ventilator-free days and lower risk of 28 day mortality.[103] Other modalities that provide a broader assessment should be incorporated into a clinician's decision to avoid delaying extubation.[104,105]

Presence of strong cough, gag reflex, and minimal secretion burden can help predict extubation success.[100,103,104] A patient can either be asked

Table 2
High-risk physiologic phenotypes with pathophysiology of collapse with intubations and individual management strategies

Physiologic Phenotype	Mechanisms of Collapse	Optimization Strategy
Refractory shock	Loss of sympathetic tone → ↓ mean systemic filling pressure and systemic vascular resistance[74] Positive pressure ventilation→ ↑ intrathoracic pressure → ↑ right atrial pressure → ↓ pressure gradient for venous return[75] Potential medication related myocardial depression at high doses → reduced cardiac efficiency[76]	Volume optimization, pre-emptive vasopressors infusions/push-dose vasopressor Optimizing ventilator settings to reduce pulmonary venous resistance Induction agent dose reduction and selection
Right Ventricular Failure and Uncontrolled Pulmonary Hypertension	Sedative related systemic hypotension → RV ischemia[77] PPV, hypercarbia, hypoxemia → ↑ PVR (↑ RV afterload) and ↓ RV pre-load → RV overload and LV underfilling → systemic hypotension → continued cycle of underfilling[77,78]	Induction agent dose reduction and selection (eg, etomidate and reduced-dose ketamine), consideration of awake intubation Ventilator settings aimed to minimize pleural pressure with lower PEEP levels Vasopressor/inotropes/VA ECMO availability[79] Experienced proceduralists with minimized apneic time and consideration of pre-emptive ECMO consultation in severe case
Obesity Supine Death Syndrome	Supine positioning → ↓ functional residual capacity and expiratory reserve volume → severe ventilation/perfusion mismatch → acute right heart failure[80,81] Frequent concurrent obstructive sleep apnea → upper airway obstruction and hypoventilation[82]	Maintaining upright positioning throughout induction with optimized pre-oxygenation with increased PEEP[80] Apneic oxygenation during laryngoscopy
Severe Hypoxemia and Shunt	Reduced oxygen reserve → rapid desaturation → myocardial ischemia, neurologic ischemia, arrhythmias, arrest[83]	Optimized preoxygenation with NIV, minimized apneic time, and apneic oxygenation during laryngoscopy[53,83]
Severe Acidosis	Apnea or reduced ventilation → worsening respiratory compensation → reduced pH → impaired cardiac contractility, vasodilation, arrhythmias[84]	Optimize acid base status prior to induction Minimize apneic time Match or increase minute ventilation immediately post-intubation
Fixed Cardiac Output States (eg, Severe Aortic Stenosis, LV Outflow Tract Obstruction)	Increased dependence on LV pre-load to maintain cardiac output + vasodilation from induction agents and PPV → ↓ venous return and LV pre-load → hemodynamic instability → myocardial ischemia[85] Tachycardia → ↓ diastolic filling time → ↓ coronary blood flow→ myocardial ischemia	Optimize hemodynamics pre-intubation with fluids/ vasopressors ECMO standby Induction agent dose reduction and selection[86] Consideration of awake intubation Avoid hypoxemia, hypercapnia, acidosis Consider utilizing succinylcholine rather than rocuronium[87]

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Table 2
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Physiologic Phenotype	Mechanisms of Collapse	Optimization Strategy
Extrinsic Compression (eg, anterior mediastinal masses and tracheal compression)	Baseline tracheobronchial compression, pulmonary artery/ cardiac compression, and/or SVC compression mediated with positioning and chest wall muscle tone + supine positioning, PPV, and loss of muscle tone → airway collapse and/or vascular compression with hemodynamic collapse[88–90]	Maintenance of spontaneous ventilation and semi-upright positioning[91] Preparation for airway rescue with rigid bronchoscopy[90] ECMO standby/pre-emptive vessel cannulation
Elevated Intracranial Pressure (ICP)	↓ MAP → compromised cerebral perfusion Sympathetic activation → ↑ ICP and reduced CPP Hypoxia and hypercapnia → cerebral vasodilation → ↑ ICP	Induction agent dose reduction and selection[92] Blunted response with opioids[93] Optimized pre-oxygenation with consideration for short term mild hyperventilation[94] Hyperosmolar therapy if critically high ICP/signs of herniation Head of bed elevation and avoidance of neck vein compression[95]

to cough voluntarily, or a cough can be stimulated via suction catheter and cough peak flow (CPF) measured during expiration. Cough tests brainstem reflex, cognitive function, and respiratory muscle strength in one maneuver.[105] In a meta-analysis, most commonly used CPF below 60 L/min indicated weak cough and was associated with 36.2% extubation failure rate compared with 6.3% in patients above the cutoff.[106] Similarly, patients with moderate to copious secretion burden are almost 2 to 3 times more likely to experience extubation failure.[107,108] Frequency of endotracheal suctioning can be used as a surrogate for secretion burden.[109] Synergistically, cough strength and secretion burden represent a key predictor of extubation failure given increased risk of aspiration in patients with reduced ability to clear their secretions. Furthermore, ensuring adequate nutrition, restoring fluid balance, electrolyte replenishment, and early mobilization can optimize the conditions for favorable respiratory muscle functioning.[98] An international consensus panel suggests performing the first extubation readiness tests as soon as the following weaning parameters are met: resolution of the initial reason for intubation, cardiovascular stability with minimal or no need for vasopressors, no continuous sedation, and adequate oxygenation defined as PaO_2/FiO_2 150 mm Hg or greater with PEEP up to 8 cm H2O.[100,110] The “acceptable” PEEP threshold may need to be individualized based on patient factors such as body habitus (eg, obesity with reduced chest wall compliance) and conditions like tracheobronchomalacia, in which higher PEEP may be required to maintain end-expiratory airway patency and oxygenation. When such patients are identified, it is also important to understand the physiology being tested by the extubation readiness tests.

Extubation readiness tests

Successful extubation relies on patient’s ability to resume spontaneous work of breathing while maintaining hemodynamic stability. There is no one gold standard test to predict the readiness of a patient’s respiratory mechanics to take over from the ventilator. Instead, extubation decisions should be based on an integrated assessment of physiologic reserve and airway safety, using tools such as a SBT, the rapid shallow breathing index (RSBI), evaluation for laryngeal edema risk (eg, cuff leak when appropriate), and, in selected patients, diaphragm assessment (eg, ultrasound) to help identify respiratory muscle dysfunction.

SBT serves as a stress test for a patient’s ability to breathe without assistance. Studies have attempted to identify optimal strategy (pressure support ventilation, PSV, vs T-piece) and duration to define an ideal SBT. In a trial including 1153 patients, participants randomized to a 30 minute SBT with 8 cm H2O pressure support had higher rates of successful extubation compared with a 2 hour T-piece SBT.[111] In another multicenter open label trial, T-piece did not result in greater ventilator-free days at day 28 and neither was there a difference in reintubation rates compared with PSV of 8 cm H2O SBT.[112] Another factorial randomized controlled trial found that a strategy of once-daily screening combined with an SBT performed using low-level pressure support resulted in the shortest time to successful extubation, compared with more frequent screening paired with the same pressure-support SBT.[113] Therefore, a PSV of 5 to 8 cm H2O with positive end expiratory pressure of 5 to 8 cm H2O would be reasonable SBT trial setting. Permanent liberation from the ventilator can be attempted if a patient does not show signs of respiratory distress and hemodynamic stability for greater than 30 minutes.

One of the most widely used tools to quantify respiratory distress is called RSBI or Yang-Tobin index.[114] RSBI is the ratio of respiratory rate to tidal volume in liters (f/Vt). In the landmark 1991 study, an RSBI less than 105 was associated with successful extubation (sensitivity 0.97 and specificity 0.64).[115] A meta-analysis in 2022 involving around 11,000 patients appraised RSBI with moderate sensitivity of 0.83 and poor specificity of 0.58.[116] The tool should not be used in isolation in predicting successful extubation. Patients in trauma ICU or with neuromuscular involvement may have normal RSBI but still fail extubation. Therefore, real-time noninvasive diaphragmatic evaluations are increasingly being used in clinical practice. In particular, diaphragmatic excursion (DE), craniocaudal displacement of the diaphragm during breathing, and diaphragmatic thickness fraction (DTF), variation in diaphragm thickness during respiration, are two common predictors.[114,117] Between these two measurements, DTF (greater than 30%) is more accurate than DE in predicting extubation success.[117,118]

Endotracheal intubation longer than 36 hours has been associated with increased risk of laryngeal edema and post-extubation stridor.[119] Post-extubation stridor is associated with increased risk of reintubation.[120] Cuff leak test (CLT) is often used to detect laryngeal edema with the understanding that absence of leak suggests laryngeal edema. According to a meta-analysis analyzing 28 studies, CLT has high specificity of 0.88 but moderate sensitivity of 0.62 to predict upper airway obstruction with similar metrics to predict reintubation.[120] The test is a powerful rule-in tool, but clinical judgment is essential in high-risk patients, such as those with traumatic intubation, prolonged intubation (>6 days), larger ETTs, or reintubation after an unplanned extubation.[119,120] Given the high specificity, clinicians should have a low threshold to intervene with corticosteroids to prevent adverse outcomes. Another meta-analysis found that in high risk critically ill patients who failed CLT, corticosteroids reduced the rate of post-extubation airway events (post-extubation stridor, laryngeal edema, and airway obstruction) by 66% and reintubation rate by 65% compared with unselected patients.[121] CLT should therefore be integrated in predicting extubation success, particularly, in high-risk patients as described earlier.

The 2017 CHEST/ATS practice guidelines recommend SBT with inspiratory pressure augmentation between 5 to 8 cm H2O rather than using T-piece or CPAP. Additionally, a protocol-guided approach is recommended to identify patient readiness for ventilator liberation. Performing cuff leak test on high-risk patients can help identify patients with post-extubation stridor with high likelihood of reintubation. Systemic prophylactic corticosteroids 4 hours before extubation in patients who fail CLT can increase odds of successful extubation.[119] While no specific protocol-driven extubation approach has been validated, a daily weaning assessment after improvement of underlying cause of respiratory failure; an SBT with PSV 5 to 8 cm H2O, PEEP 5 to 8 cm H2O, FiO_2 less than 0.4 to 0.5; and an extubation attempt in the event of meeting the above criteria is a reasonable approach. A proposed framework is illustrated in **Fig. 3**.

Post-extubation support

Withdrawal of MV and PPV restores patient's native respiratory metabolic demands, and increases LV pre-load and afterload due to abrupt decrease in the intrathoracic pressure.[22] Common causes of post-extubation failure include respiratory failure, congestive heart failure, aspiration or excessive secretions, and upper airway obstruction.[122] Initiating prophylactic respiratory support immediately post-extubation in high-risk patients reduces rates of reintubation and improve outcomes. High risk features include COPD, congestive heart failure, hypercapnia, older age, morbid obesity, and a higher illness severity.[100,123] NIV reduces reintubation rates in hypercapnic patients with chronic respiratory disorders, congestive heart failure, and morbid obesity.[102,124] Furthermore, the combination of NIV and HFNC in a randomized controlled trial showed reduced rates of reintubation compared with HFNC alone.[125] It is important to note that these benefits are only realized when applied immediately after extubation

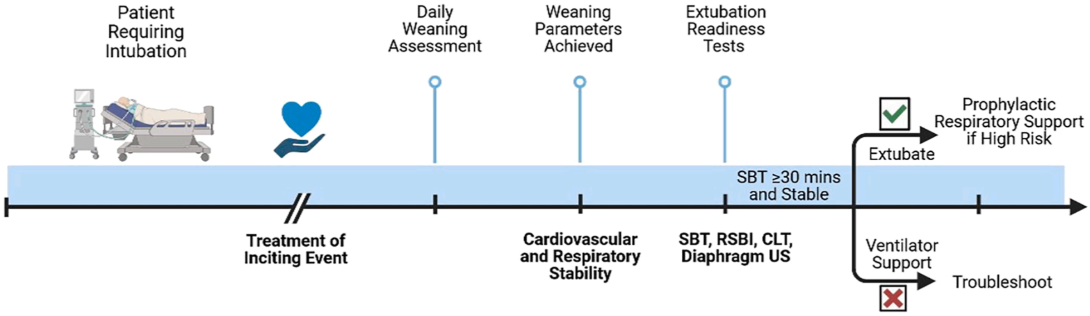

Fig. 3. Timeline of key events from intubation to successful extubation.

and are even associated with increased mortality when used as rescue therapy. These findings are strongly recommended in the 2017 ATS/CHEST clinical practice guidelines.[102]

SECTION 5: SUMMARY

Endotracheal intubation remains a cornerstone intervention in the management of critically ill, yet it carries profound physiologic consequences that extend beyond airway control. Although clinical indications for intubation are well described, determining the optimal timing for intubation remains challenging, and current evidence does not support a single physiologic threshold that reliably defines the ideal moment. Once intubation is decided, careful anticipation of potential complications and meticulous preparation are essential. Optimization of hemodynamics, pre-oxygenation, thoughtful medication selection, appropriate induction strategy, procedural technique, and vigilant post-intubation management all play critical roles in minimizing peri-intubation risk. Importantly, MV should be viewed as a temporary supportive therapy rather than a definitive treatment. From the time of intubation, clinicians should adopt a forward-looking strategy that prioritizes liberation from MV. Daily assessment of readiness for extubation, confirmation of resolution or improvement of the precipitating cause of respiratory failure, and structured evaluations such as SBTs are central components of this process. A physiologically informed and anticipatory approach—from intubation to extubation—remains fundamental to optimizing outcomes in critically ill patients.

CLINICS CARE POINTS

Pearls

- Hypoxemia, hypercapnia, changes in pulmonary vascular resistance, transpulmonary pressures, pre-load, and afterload are expected in critically ill patients undergoing intubation and initiation of MV.
- Indications for intubation in the critically ill are diverse and include respiratory failure, airway protection, neurologic failure, trauma, among others, but physician judgment, risk assessment, and patient autonomy remain the cornerstone when deciding to intubate.
- Induction should be treated as a hemodynamic stress test and stabilizing patients should be prioritized before administering sedatives or initiating positive pressure ventilation.
- Anticipating the effects of sedation and positive pressure ventilation on an individual patient's pathophysiology can reduce peri-intubation complications.
- Consider SBT utilizing PSV of 5 to 8 cm H2O with individualized PEEP tailored to patient profile over 30 minutes rather than T-piece trial.
- SBT can unmask reasons for extubation failure. Failure to actively identify and reverse the cause of a failed SBT will delay successful extubation.

Pitfalls

- There is no perfect timing for intubation in the critically ill; clinician should decide on a case-by-case approach.
- Waiting to intubate until the patient severely decompensates limits the opportunity for safe pre-induction stabilization.
- Failure to prepare vasopressors and anticipate hypotension can contribute to avoidable peri-intubation collapse.
- Avoid performing multiple SBTs within a 24 hour period if the cause of initial SBT failure is not readily identified and corrected
- Do not initiate NIV as a rescue measure, as opposed to immediate prophylactic use in high risk patients, after emergence of overt respiratory distress following extubation

FINANCIAL SUPPORT

None.

DISCLOSURE

The authors report no conflicts of interest related to this work.

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