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Bedside Approach to
Ventilatory Management

Chapter

7

Evidenced-based Selection of Invasive Ventilation

Aravinth S, V Dedeepiya Devaprasad

INTRODUCTION

Invasive ventilation is a basic yet one of the most vital weapons in the intensivist's armamentarium that aids in managing patients in the critical care unit. Its initiation, maintenance, and cessation are both a science and an art. Over the years, experience with patients requiring invasive mechanical ventilation has suggested that selecting patients for invasive ventilation is predominantly a clinical decision. The available literature is scarce about the criteria for the selection of patients. The chapter will review the available evidence for an appropriate, evidence-based selection of invasive mechanical ventilation.

The universal ABCD (airway, breathing, circulation, and neurologic disability) approach systematically followed is also applicable here. Once that is addressed, the specific clinical conditions of the patient that might warrant invasive ventilation should be addressed.

A. Airway Diseases

The assessment of patency and the ability of the patient to protect the airway is key in deciding the need to secure the airway with definitive measures and should be done with due diligence. The best tool to assess the patient's airway is to test their ability to phonate. Suppose the patient can speak clearly and answer the clinician's questions appropriately. In that case, it denotes a patent airway, adequacy of ventilation, optimal functioning of the vocal cord, and reasonable cerebral oxygenation.[1] The concept that the level of alertness required to maintain a tone of the airway and that is required to exhibit adequate protective reflexes to avoid aspiration of gastric and oral fluids are similar, drives this idea of assessing the adequacy of phonation. Further, the ability to swallow secretions is a protective reflex against aspiration. Notably, the gag reflex is not an indicator of airway protection or closure of the larynx. It correlates poorly with the Glasgow Coma Scale (GCS).[1] A patient with pooling of secretions with an inability to swallow requires intubation and initiation of invasive ventilation irrespective of his alertness, as commonly seen in patients with neuromuscular disorders such as Guillain-Barré syndrome.

Upper airway obstruction is frequently characterized by a muffled or "Hot Potato" voice, an inability to swallow secretions due to pain or obstruction, stridor, and dyspnea. The obstruction could be at the level of either the upper airway or the lower airway. Further, an obstructed airway challenges adequate gas exchange and can lead to respiratory failure. A focused airway examination with careful assessment of the mouth and oropharynx to look for signs of an anticipated difficult and threatened airway forms the cornerstone of initiating an invasive ventilatory therapy in these patients, as any delay in recognition and delayed intubation could be catastrophic.

Early airway securement is critical in some cases, such as inhalation burns or trauma resulting in neck swelling. In these situations, a mild hoarseness of voice indicates the need for emergency endotracheal intubation and the initiation of invasive ventilation.

Table 7.1: Clinical features of an airway injury in inhalational burns

	Clinical features
Symptoms (to be elicited from patient's presentation and history)	• Stridor • Drooling • Hoarseness • Dysphagia
Signs (to be elicited from physical examination)	• Facial burns • Soot in the nasal cavity • Perioral burns • Singed nasal hairs
Laryngoscopic signs	• Significant edema • Soot particles • Blisters • Ulcerations

B. Breathing Abnormalities

The ability to maintain adequate gas exchange with normoxia and normocarbia is vital to the physiological functioning of the various tissues. Any inadequacy in this regard warrants escalation to higher modes of ventilatory therapy—both hypoxemic and hypercapnic respiratory failure at their extremes mandate invasive ventilation. Although non-invasive positive pressure ventilation and high-flow nasal cannula therapy have been widely used with good success, patients with severe hypoxemia and hypercapnia frequently require invasive mechanical ventilation. A detailed review of the various common conditions causing respiratory failure has been discussed in the subsequent sections.

C. Circulatory Compromise and the Initiation of Invasive Ventilation

Circulatory shock with hemodynamic compromise is one of the most common indications for the initiation of invasive ventilation in the ICU. The decision to proceed with endotracheal intubation of a critically ill patient with septic shock relies on multiple vital clinical factors. It has been shown that the complications due to delayed intubation are often avoided by initiating invasive ventilation early in these patients in the initial twenty-four hours of septic shock. Delaying intubation in patients who present with acute respiratory distress as a result of septic shock and inadvertent dependence on non-invasive ventilation in such a scenario has shown higher rates of mortality.[2]

Among patients with shock, the ability to maintain a patent airway does not necessarily translate into adequate cellular oxygenation and aerobic metabolism. Defective oxygenation is not correctable despite supplemental oxygen. It poses an emergent threat to life and necessitates intubation. Severe hemodynamic compromise results in inadequate tissue perfusion, causing an increase in metabolic debt and significantly affecting the muscles of respiration. This leads to progressive respiratory fatigue, and respiratory failure often supervenes. In these patients with shock, intubation and mechanical ventilation improve tissue oxygenation and decrease metabolic demands, eventually decreasing the metabolic debt burden.[1] It has been demonstrated that dysfunction of the diaphragm may occur even in the initial 4 hours of septic shock. With such patients anticipated to deteriorate further, intubation and initiating invasive ventilation is a safe practice in patients with circulatory compromise.[3]

The INTUBATIC study concluded that neurological and respiratory parameters and hemodynamic factors only partially explained the need for endotracheal intubation in patients with septic shock. (A major fraction of the variability of intubation could not be explained by patient-related parameters.) This, in part, explains the invaluable role of clinical decision-making in deciding the initiation of invasive ventilation in this cohort of patients.[3]

There is no recommended vasopressor dose beyond which intubation is recommended; however, it is usual practice and common sense to intubate patients with an escalating dose of vasopressors or worsening acidosis (including lactic acidosis) early.

D. Neurological Disability

The trauma literature recommends that intubation and mechanical ventilation be initiated for airway protection and to ensure normocapnia. Severe head trauma patients (GCS less than or equal to 8) are a definitive indication for intubation and mechanical ventilation, while in patients with moderate head injuries (GCS 9–12), the institution of intubation and invasive mechanical ventilation relies on other clinical parameters.[4]

INITIATION OF INVASIVE VENTILATION IN SPECIFIC CONDITIONS

A. Bronchial Asthma

It is well known that survival rates for asthmatic patients who are intubated promptly remain between 80–100%. A major fraction of studies have demonstrated a mortality rate of less than 10% when these patients are intubated appropriately.[5] However, patients presenting with an acute exacerbation of bronchial asthma often pose a dilemma to clinicians on the appropriate time to intubate and initiate mechanical ventilation. The complexity of putting together various clinical and laboratory parameters is often the reason for heterogeneity in the clinical decision to intubate.

Any patient with asthma is defined to have a severe asthmatic exacerbation when dyspneic at rest and is comfortable only when he assumes the upright position. Patients who breathe faster than 30 breaths per minute use accessory respiration muscles with tachycardia (pulse rate of more than 120). Pulsus paradoxus (more than 25 mm Hg) are likely to need intubation.[6]

However, it must be reiterated that invasive mechanical ventilation is not the primary treatment for acute severe asthma. An essential treatment measure is the prompt administration of systemic corticosteroids and adequate delivery of inhaled bronchodilators, preferably by nebulization therapy. However, patients without an adequate response to these measures and with continued respiratory distress will need intubation.

ABG is a common assessment tool, and the relevance of increased PCO_2 levels has to be clarified here. Patients with severe acute asthma are tachypneic, which results in low PCO_2. The associated tachypnea in these patients is the cause of the low PCO_2. A normal PCO_2 on a follow-up ABG in these patients should be treated cautiously, as it is likely due to clinical exhaustion. This "pseudo normalization" of PCO_2 was always considered an ominous sign and often signaled the need for intubation.[7] However, another school of thought is that an elevated PCO_2 in isolation might not necessitate intubation if the patient is not exhausted and has a normal mental status. A systematic review by Leatherman concluded that intubation might not be necessary for a favorable outcome in most asthmatic patients with hypercapnia. A serially rising $PaCO_2$ which is refractory to treatment and associated with mental status changes necessitates invasive ventilation.[8]

There have been a few clear indications in the literature from clinical experience. However, no major body of high-quality evidence that warrants intubation and the initiation of mechanical ventilation has stood the test of time.

1. Cardio-respiratory arrest, physical exhaustion, altered sensorium in the form of lethargy or agitation, profound bradypnea that potentially interferes with oxygen delivery or anti-asthma therapy, and profound bradypnea necessitate the initiation of invasive mechanical ventilation.[8]
2. Asthmatic patients with any level of PCO_2 should be clinically assessed and receive maximum medical therapy, as outlined before. If they are not in impending arrest or experiencing extreme exhaustion, if the response to maximal medical therapy is suboptimal clinically and on an ABG (failure to reduce PCO_2 in those with high initial PCO_2), intubation is necessary. Likewise, the pseudonormalization of PCO_2 in those with an initial low PCO_2 after maximum therapy would also be an indication for intubation. Thus, clinical judgment is the key at all points in time when determining the need for endotracheal intubation.

B. Chronic Obstructive Pulmonary Disease (COPD)—When do we Initiate Invasive Ventilation?

A vast majority of patients with COPD undergo a trial of non-invasive ventilation prior to invasive ventilation. However, a subset of patients would need immediate, invasive mechanical ventilation. These include patients with features of life-threatening respiratory failure: cardiopulmonary arrest, those with agonal breathing, patients with severe respiratory

Table 7.2: BAP-65 scores for assessment of severity of COPD[9]

Parameter	*Points*
BUN ≥25 mg/dL, or	1 point
Impaired mental status (GCS <14 or stupor, disorientation, or coma)	1 point
Pulse rate of 109 beats/min or greater	1 point

Table 7.3: Classification of severity of COPD according to BAP-65 score[9]

Class	*BAP*	*Age*	*Mortality (In-hospital)*	*Need for mechanical ventilation within 48 hours*	*Recommendation*
I	0	Less than 65 years	0.3%	0.3%	
II	0	Greater than or equal to 65 years	1.0%	0.2%	Routine management of COPD exacerbation
III	1	Any age	2.2%	1.2%	Consider early non-invasive ventilation and/or ICU care
IV	2	Any age	6.4%	5.5%	
V	3	Any age	14.1%	12.4%	

Adapted data from Tabak YP et al.[9]

distress not fit for NIV, and concurrent severe hemodynamic instability. BAP-65 is a bedside scoring system used to assess the necessity for invasive ventilation in patients with acute exacerbations of COPD. In a study by Tabak YP et al, any patient with four risk factors, namely impaired mental status, raised blood urea nitrogen, age greater than 65 years, and pulse rate greater than 109 beats/min, carried a higher risk of requiring mechanical ventilation as compared to those with none of these risks. Hypoxemia that is refractory despite supplemental oxygen and severe respiratory acidosis and is not responsive to therapy and the NIV signals the need to consider intubation and the initiation of mechanical ventilation.[9,10]

C. Neuromuscular Diseases

Patients with neuromuscular disorders can develop acute respiratory failure. They can also present with an acute exacerbation of chronic respiratory failure. In addition, they are predisposed to recurrent aspiration and pneumonia. Patients who need immediate invasive mechanical ventilation are those who present with cardiorespiratory arrest, life-threatening respiratory distress, or altered consciousness. Further, more those patients with severe bulbar dysfunction and risk of aspiration cannot be initiated on NIV and warrant an early intubation and initiation of invasive ventilation. It is valuable teaching to initiate invasive mechanical ventilation early before it is needed emergently.[11] This can be employed as a preemptive measure to reduce the likelihood of developing early-onset pneumonia in patients suffering from acutely progressive neuromuscular weakness. The subset of patients who present with established aspiration pneumonia with or without severe respiratory failure warranting intubation and the initiation of invasive ventilation.

Patients with neuromuscular weakness who may clinically progress to respiratory failure often report

1. Dyspnea—a feeling of "suffocation or drowning," especially when the patient assumes a supine posture.
2. Severe difficulty swallowing—ineffective cough with difficulty clearing secretions. This can be clinically assessed by asking the patient to cough and spit out sputum.
3. Speech disturbances—hypophonia, pausing while talking to "take a breath," increased respiratory rate while speaking, progressive decline while continuing to speak in the ability to speak, tone of speech, or speech clarity all point to respiratory muscle weakness. Thus, a clinical speech assessment is essential.

Assessment of respiratory patterns is also important in these patients. Tachypnea, shallow breaths, paradoxical abnormal breathing patterns, and the use of accessory muscles all point to an evolving respiratory failure needing mechanical ventilation. Single breath count (SBC) is a simple bedside test performed by a patient who, after maximal inhalation, is asked to count at the rate of 2 counts per second for as long as possible without stopping to breathe. SBC less than 20 indicates the abnormal respiratory function, and these patients need to be closely monitored before initiating mechanical ventilation. The use of a bedside spirometer to assess the maximal inspiratory pressure (MIP)—also called the "negative inspiratory force" (NIF)—vital capacity (VC), and maximal expiratory pressure (MEP) and the infamous 20:30:40 rule help to identify an impending respiratory failure. A VC of less than 20 mL/kg, MIP of less than –30 cm H_2O, and MEP of less than 40 cm H_2O are useful bedside tools to identify impending respiratory failure.[12] It is also important to access the neck lift. An inability to lift the head (unsupported by a pillow) off the bed for less than 5 seconds is a sign of neck flexor weakness. This may be an indicator of respiratory muscle weakness.

D. Patients with Acute Respiratory Distress Syndrome

From clinical experience, we know that most centers use invasive mechanical ventilation for patients with moderate (i.e. arterial oxygen tension/fraction of inspired oxygen [PaO_2/FiO_2] $\leq$200 mm Hg on positive end-expiratory pressure [PEEP] $\geq$5 cm H_2O) or severe ARDS. Non-invasive ventilation is most often reserved for those with mild ARDS. Use of NIV in mild ARDS is possible only when the patient has stable hemodynamics, is easily oxygenated, and has no other indications for immediate intubation.

However, some centers use NIV in moderate to severe ARDS as well. The data and literature, however, are interesting in this regard. The authors of the LUNG-SAFE study conducted a subset analysis that demonstrated that NIV in ARDS patients with a PaO_2/FiO_2 ratio of 150 mm Hg was an independent predictor of mortality, emphasizing the importance of using NIV with caution in this patient population.[13]

Kangelaris et al studied the timing of intubation and clinical outcomes in 457 patients with ARDS. The study demonstrated that patients who were not intubated had reduced morbidity and disease severity compared to patients requiring invasive ventilation. However, this is only a tiny part of the bigger picture. The 60-day mortality was identical (36%) for intubated vs non-intubated). Further, among the 106 patients who were not intubated, nearly 34% (36 patients) were intubated within three days of follow-up and initiated on mechanical ventilation. The subgroup of patients who were intubated late showed higher mortality at 60 days (56%) than the subgroup of patients who were intubated (36%) and those who did not need intubation at all (26%). This increased mortality among patients intubated late was present even after two years. The study concluded that late intubation was associated with increased mortality in ARDS.[14]

Thus, an appropriate clinical judgment and a multifactorial approach while deciding on intubation are vital in managing patients with ARDS.

E. Invasive Ventilation following NIV Failure

Failure of non-invasive ventilation (NIV) has been considered a definite indication for initiating invasive ventilation. In a study by Jun Duan et al, NIV failure was defined as the need for tracheal intubation following initial therapy with NIV due to the presence of one or more of the following reasons: cardio-respiratory arrest, inability to maintain a PaO_2/FiO_2 of more than 100, the occurrence of situations necessitating intubation for airway protection or to clear excessive tracheal secretions, severe breathlessness, hemodynamic compromise not responding to vasoactive agents and fluids, and failure of signs of respiratory muscle fatigue to resolve.[15]

NIV is extensively used in both type I and type II respiratory failure before initiating invasive ventilation. It decreases the requirement for intubation in acute respiratory failure by reducing the work of breathing. Antonelli et al showed that NIV initiated as initial management in ARDS precluded endotracheal intubation in 54% of patients. Further, the study stated that a Simplified Acute Physiology Score II (SAPS II) greater than 34 and failure to increase PaO_2/FiO_2 despite 1 hour of NIV predicted NIV failure.[16]

It has been shown that the failure rate of NIV remains high in hypoxemic respiratory failure, ranging between 25 and 59%. This demonstrates that not all patients benefit from NIV, and thus invasive ventilation remains the definitive mainstay of treatment. This necessitates a prediction tool to recognize patients at risk of NIV failure. Jun Duan et al developed a novel tool called the HACOR scale (which considers heart rate, acidosis, consciousness, oxygenation, and respiratory rate) to predict NIV failure in hypoxemic respiratory failure.

The authors concluded that the HACOR scale was effective in predicting NIV failure in the setting of hypoxemic respiratory failure. A single variable has been shown to have a lesser predictive value for NIV failure. The chance of NIV failure increased with increasing scores, with scores above 5 carrying a very high risk, and these patients may demonstrate mortality benefits from early intubation. It is an effective bedside tool for predicting the risk of NIV failure.[15]

A recent study by Jun Duan has also demonstrated the application of the HACOR score in NIV failure among COPD patients. It has, in particular, been shown to be effective in predicting early NIV failure (less than 48 hours). In conclusion, the decision to initiate invasive ventilation in a patient on NIV depends on both clinical judgment and the presence of risk factors for NIV failure.[17]

F. Invasive Ventilation Following Failure of High Flow Nasal Cannula Therapy

HFNC has been used extensively in acute hypoxemic respiratory failure and its use has increased tremendously ever since the COVID-19 pandemic. With the clinical application of HFNC growing rapidly, it is worthwhile to understand the factors that predict HFNC failure. This helps clinicians predict patients at risk of failure of HFNC therapy and initiate invasive mechanical ventilation.

The FLORALI trial, demonstrated reduced ICU mortality and 90-day mortality with HFNC therapy in acute hypoxemic respiratory failure. Further, HFNC therapy also increased ventilator-free days among these patients. The post-hoc analysis showed that patients on HFNC therapy among the subgroup of patients with a P/F ratio less than 200 had lower intubation rates. However, it is prudent to recognize the patients on HFNC who are at risk of failing HFNC therapy and initiate invasive ventilation in these patients.[18]

The respiratory rate oxygenation (ROX) index described by Roca et al, as a ratio of SpO_2 /FiO_2 to respiratory rate, is considered a useful parameter to monitor the responsiveness to HFNC therapy. A few studies have inconsistently concluded heart rate, APACHE II score, oxygenation, delirium, respiratory rate, SOFA score, and thoracoabdominal asynchrony as predictive factors for HFNC failure.[19]

Zhen Junhai et al evaluated the utility of ROX index to predict the outcome of HFNC therapy. The review demonstrated that the ROX index had a low sensitivity despite an acceptable specificity. Although there is no widely accepted cut-off value of the ROX index with values used in various studies ranging from 2.7 to 9, a value of greater than 5 has shown a higher discriminatory accuracy. Most studies have reported 6 hours as the acquisition time of the ROX index.[20] But studies including other acquisition times of the ROX index have been sparse. In their meta-analysis, Prakash J et al revealed that acute hypoxemic respiratory failure in patients with COVID-19, the ROX index has good predictive accuracy for predicting HFNC failure.[21]

ROX index is a simple and reasonably promising tool to predict patients with a greater risk of HFNC failure. Careful monitoring of patients with a lower value of ROX index is warranted and this subset of patients must be evaluated closely for initiating invasive ventilation.

Conclusion

The decision to initiate invasive mechanical ventilation in any patient is not based on a single factor. There are currently no guidelines that summarize all the indications to initiate invasive ventilation in the available literature. The evidence-based selection for invasive ventilation depends on clinical judgment incorporated with the available literature. Around

86% of clinicians in a declarative international survey concluded that the decision to initiate invasive ventilation stemmed from "human physiological data" or "common sense." Thus, amidst all the literature, the role of a good clinical assessment is invaluable.

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