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RESEARCH ARTICLE

Airway Management for the Critically Ill Patient in the Emergency Department

Jennifer Stahl, MD*[1,2] and John O'Donnell, DO[1]

[1]East Carolina University, Department of Internal Medicine, Division of Pulmonary and Critical Care Medicine. 600 Moye Blvd, 3E-149, Greenville, NC 27834

[2]East Carolina University, Department of Emergency Medicine. 600 Moye Blvd, Mail Stop 625, Greenville, NC 27834

*stahlj@ecu.edu

ABSTRACT

Airway management is both a fundamental skill and resuscitative treatment that has taken a prominent role in emergency medicine. In the past few decades there have been many advancements in airway management particularly in critically ill patients. Technology has been developed and adapted to provide improved visualization for endotracheal intubation as well as supportive strategies for oxygenation and optimization of medications. In this review we will discuss the current practices and literature in airway management of critically ill patients including medication optimization and airway visualization techniques for first pass success.

Main Body

Acute respiratory failure is a common patient presentation to the hospital and is often managed initially in the Emergency Department. Due to the emergent nature and frequently acute presentation, this becomes a high-risk procedure with first pass success and patient safety being of the utmost importance.[1] Over the past few decades, advancements in medical therapies and treatment of chronic comorbid conditions have led to more complexity in critically ill patients presenting to the Emergency Department. In response to this, there have also been many advances in airway management to help facilitate treatment in these patients.[2] The objective of this review article will focus on current practices and literature in airway management of critically ill patients presenting to the Emergency Department.

Non-Invasive Positive Pressure Ventilation

Non-invasive positive pressure ventilation (NIPPV) has revolutionized acute airway management for the emergency provider. [3,4] With the introduction of Continuous Positive Airway Pressure (CPAP) or Bilevel Positive Airway Pressure (BIPAP) ventilation, endotracheal intubation rates for patients with acute hypoxic and/or hypercapneic respiratory failure have been decreased.[5] Not only has NIPPV become an effective treatment for short term airway support but can also be a successful means of apneic oxygenation for critically ill patients requiring endotracheal intubation.[6] Rapid sequence intubation has become gold standard in the Emergency Department with high association with airway visualization, first pass success rates, and a decrease in aspiration risk. [7]

Rapid Sequence Intubation

Rapid Sequence Intubation (RSI) includes a 3-step process: pre-induction, induction, and paralysis. The goals of pre-induction and induction are to blunt the catecholamine reaction during laryngeal stimulation and paralytic infusion. The use of sedatives during RSI is vital for patient comfort as well as hemodynamic homeostasis. Paralytic infusion is utilized for optimal airway visualization and increases first pass success rates.[7] [8] [9] In critically ill patients the administration of RSI medications can be extremely complicated due to the wide variety of hemodynamic profiles. Studies have shown that RSI practices vary among emergency physicians likely due to individual tailoring of medications to hemodynamic profiles and patient presentations. [7] A superior RSI medication combination has yet to be proven via head-to-head trials and therefore the choice of RSI medication should be tailored to the goals of treatment and hemodynamic homeostasis of patients.

Induction and Paralytic Agents for Rapid Sequence Intubation

Induction Agents

Medications chosen for induction can be just as important for patient outcomes and first attempt success as any other measure. Ideal properties for medications include short time of onset, duration, and half-life as well as minimal side effect profile. Many medications can be used to intubate the critically ill patient in the emergency department, and this section will focus on those most commonly used. The pharmacokinetics, physiologic effects, and medication properties will aid in choosing those that best fit particular hemodynamic profiles.

Fentanyl is a synthetic, highly lipophilic, centrally acting opioid and provides significant analgesic properties. Unlike morphine, it also lacks histamine release that tends to cause systemic vasodilation and subsequent hypotension. Fentanyl also significantly blunts the body's sympathetic response which is advantageous in patients where this would be deleterious such as aortic aneurysms or dissections. These properties make fentanyl an ideal medication for analgesia during induction.[10] The dose most commonly used is 1-3 mcg/kg given over 60 seconds, its onset is roughly 30 seconds with a half-life of 2-4 hours.[11] A common concern when administering fentanyl is rigid or wooden chest syndrome. However this is rare after single doses especially under 200 mcg.[12] Fentanyl does have a medium risk for inducing serotonin syndrome and should be avoided if possible in pregnant patients, since it carries a category C classification by the FDA.[13]

Propofol is a lipid soluble GABA agonist commonly used for induction and maintenance of sedation. This medication has mild bronchodilatory properties, decreases intracranial pressure, and is safe to use in pregnant patients (category B) as well as those with hepatic or renal failure.[14] The recommended dose of propofol is 1.5 mg/kg, and with an onset of 15-45 seconds and a half-life of only 5-10 minutes, it seems like an ideal agent.[15] However, one of the major drawbacks of this medication is that it can cause significant hemodynamic changes given its beta and calcium

channel activity, and can provoke bradycardia, hypotension, and reduction in ejection fraction.[16] Propofol has advantages for use in patients with neurologic disease states (hypertensive intracranial bleeds, intracranial tumors, etc) as it can reduce elevated intracranial pressure. While propofol's effect of hypotension can often be mitigated by preload administration (ie: Intravenous Fluid), not all patients have hemodynamic profiles that tolerate this (ie: severe heart failure, etc).[14]

Midazolam is the most highly lipophilic benzodiazepine and rapidly crosses the blood brain barrier with GABA agonistic properties.[12 17] With an induction dose of 0.1-0.3 mg/kg, it has a rapid distribution with onset of 60-90 seconds and provides a sedative effect for 1-4 hours.[11] Midazolam has a synergistic effect with concomitant opioid use, which allows for a more profound effect with a lesser dose when administered appropriately. However, this synergy can also lead to severe respiratory and cognitive depression when not accounted for.[17] In addition to intravenous (IV) administration, midazolam can also be administered intramuscularly (with a delayed onset of roughly 15 minutes) which might be advantageous when intravenous access is unavailable [11]. Midazolam should be used with caution in patients with impaired hepatic and renal metabolism and should be avoided in all pregnant patients (category D).[11,17]

Etomidate is a GABA receptor agonist and provides sedation and amnesia without analgesia.[18] The dose for induction most used is 0.3 mg/kg, the onset of action is 30-60 seconds, peak effect of 1 minute, and half-life is 2.5-3.5 hours.[17,18] It has minimal effect on the cardiovascular system and when compared to both propofol and midazolam, it is associated with significantly fewer rates of hypotension in patients over the age of 50 years.[19] More recently, small studies have associated etomidate with increased adrenal suppression in a variety of patient populations, however many of these studies are small and underpowered and more robust research needs to be done.[18] Like fentanyl it carries a category C classification by the FDA for pregnant patients, and although not directly contraindicated, should be avoided if possible.[20]

Ketamine is a NMDA receptor antagonist that has gained much popularity for its use in the Emergency Department for both procedural sedation and induction for intubation.[21] The recommended dose for induction is 1.5-2 mg/kg, with an onset of 30 seconds and a half-life of only 5-10 minutes. Unlike propofol and midazolam, it has decreased rates of hypotension in patients over the age of 50 years.[11,21] At the correct dose ketamine can cause amnesia and analgesia as well as an added benefit of bronchodilation. Ketamine does not negatively affect cardiac output and is not associated with hypotension.[21] Previously, it was believed that ketamine resulted in increased intracranial pressure. However, this has been disproven.[22] Given its hemodynamic properties, some physicians have been administering it concomitantly with propofol for RSI, referring to it as "ketofol". While the clinical data regarding this strategy is limited, early studies suggest that this combination has similar hemodynamic effects to that of etomidate.[23]

Paralytics

In the critically ill, potentially unstable patient, the ability to rapidly obtain a stable airway and limit any further complications can have a significant impact on a patient's morbidity and mortality. Multiple studies have shown that use of paralytics with intubation improves intubating conditions, first-attempt success rates as well as number of attempts, while also decreasing aspiration risk, hypoxemia, airway trauma, and death.[24-27] The two most common agents studied in literature and used for RSI are succinylcholine and rocuronium.

Succinylcholine is the only depolarizing paralytic widely available for use in RSI and works by reversibly binding to the motor neuron acetylcholine receptors resulting in repetitive firing and stimulation of skeletal muscle resulting in depolarization.[28,29] The standard induction dose is a one-time administration of 1-2 mg/kg IV with an onset of action of 60-90 seconds and a half-life of 3-6 minutes. Succinylcholine also has the option of intramuscular (IM) administration at 3-4 mg/kg with a delayed onset of action at roughly 3 times that of IV administration.[28] The short duration of action makes this medication very appealing for RSI in critically ill patients who are deemed high-risk intubations and those where a rapid assessment of the patient's neurologic examination is important, such as those with severe neurologic injuries.

Malignant hyperthermia is a rare side effect of succinylcholine and occurs in less than 0.01% of cases.[30] More commonly, hyperkalemia is a major concern. In the average patient the increase in potassium ranges from 0-1.0 mEq/L. However, the increase in potassium can be much more profound in patients with burns, crush injuries,

congenital and acquired myopathies, and neurologic diseases (stroke, spinal cord lesions, ALS, and MS).[14,16,31] Of note, in patients with denervating diseases, succinylcholine is safe to use in the acute injury phase as up-regulation of the acetylcholine receptor does not significantly increase until sometime after the first week after initial injury.[28,31] Caution should be used with repeat doses as this can lead to prolonged muscle weakness and increased vagal tonicity resulting in bradycardia and hypotension.[31]

Rocuronium is one of multiple non-depolarizing paralytics available and is widely used since it has the shortest duration of action.[32] The standard dose ranges from 0.6 to 1.2 mg/kg resulting in full paralysis after 1-2 minutes. Compared to succinylcholine, the half-life of rocuronium is significantly longer at 30-60 minutes after initial administration.[33] Given the extended duration of action, when intubating a critically ill patient, the clinician must be able to easily bag-valve-mask ventilate the patient before considering using this agent as a paralytic. Even though the reversal agent, sugammadex, is now commercially available, it is often not readily accessible in the event of failed intubation. It is also imperative to start sedation shortly after successful intubation as the paralytic effect will often outlast the sedation from induction agents. Some patients taking chronic non-depolarizing muscle relaxants or chronic anticonvulsant therapy may exhibit paralytic resistance. On the other hand, there can be significantly increased potency in patients with metabolic acidosis or alkalosis and those with chronic neuromuscular diseases.[31]

When it comes to choosing the optimal paralytic agent for a critically ill patient, multiple factors need to be considered. Individual studies have been largely equivocal in determining whether succinylcholine or rocuronium is superior. A systematic review found that succinylcholine was associated with significantly improved intubating conditions compared to rocuronium likely due to shorter onset and duration.[32,33] Both paralytic agents have been used during pregnancy and do not cross the placenta. Rocuronium is category B and succinylcholine is category C FDA classification in pregnancy.[34]

Airway Management in the Critically Ill Patient

Difficult intubations requiring >2 attempts have been found to have a 7-fold increase in complication rates with the most significant being hypoxemia, aspiration, bradycardia, and death[35]. This section will focus on a variety of techniques and practices that can be used during endotracheal intubation and managing the difficult airway of critically ill patients. These practices have been shown to decrease rates of complications either directly or indirectly.

Apneic Oxygenation

Apneic oxygenation is the concept of providing supplemental oxygen to the nonbreathing patient to prevent hemoglobin desaturation and has been studied since 1959.[36] Despite the initial evidence of preventing desaturation in apneic volunteers for up to 55 minutes, its clinical benefit has been questioned over the years, especially after the FELLOW Trial in 2016.[37] Following this, pooled data from multiple studies found apneic oxygenation to significantly reduce patient hypoxemia during intubation without affecting the difficulty or first attempt success rate and showed a trend towards a reduction in patient mortality.[38] Generally, the nasal oxygen modality (ie: nasal cannula with or without a reservoir, high-flow nasal cannula, or nasal CPAP) used for the preoxygenation phase is left on the patient as they are induced to provide apneic oxygenation. While NIPPV for apneic oxygenation has not been shown to decrease hypoxia in comparison to high flow nasal cannula, the combination of NIPPV and HFNC has been shown to reduce the level of oxygen desaturation and more studies should be performed to study this combination further.[6,39]

Video Laryngoscopy

The Video Laryngoscope (VL) emerged in the early 2000s, and has increasingly gained wide acceptance in not only the emergency department but also in pre-hospital, intensive care unit, and operative settings. VL utilizes a camera at the tip of the laryngoscope blade to augment visualization.[40] Advantages of VL use include improved visualization of difficult airways (anterior, small oropharynx, neck immobilization, etc.), expansion of view to other team members, and the option for use of hyper-angulated blades with rigid stylets to access difficult airways. Disadvantages include lens fogging or obscuration by fluids, and potential difficulty with placing the ETT in same path as the laryngoscope.[41]

There have been multiple head-to-head studies looking at Direct Laryngoscopy (DL) vs Video Laryngoscopy (VL) with varying results. In a 2017 Cochrane Review of 64 randomized controlled trials (7,044 participants), VL did not

show a reduction in the number of intubation attempts, incidence of hypoxia or respiratory complications, or a change in time required for intubation when compared to DL.[40] However, it should be noted that significant heterogeneity was observed across studies relating to a lack of data on clinical location and impact of obesity on failed intubation rates.[41,42] The question of whether VL reduced the number of failed intubations, in particular those with difficult airways, was not addressed. Head-to-head studies have compared VL and DL in various settings (simulation, ED, Intensive Care Unit, and operative room), and across varied operator experience levels (students, residents, fellows, supervising/attending physicians) and specialty training backgrounds.[42] Owing in part to this heterogeneity in design and populations studied, results have been conflicting regarding the superiority of VL as it pertains to first-pass intubation success, time to intubation, and peri-intubation hypoxia.[40,41]

When it comes to intubating the critically ill patient, there is no substitute for experience regardless of the intubation technique. Across multiple studies the more experience a provider has at intubating, the higher their first attempt success rate is and the lower their complication risk.[35] Prior to reaching this level of proficiency (roughly 100 intubations) video laryngoscopy (VL) has repeatedly shown significant superiority over the direct approach in the in-experienced provider.[43,44] When compared to direct laryngoscopy (DL) in a meta-analysis, video laryngoscopy has improved ease of intubation, visualization, decreased esophageal intubations and increased first attempt success rate by two fold.[45] More recently, when compared head-to-head in over 12,800 difficult airways in the Emergency Department, VL had a 11.4% higher first-pass success rate and a 2-3 fold lower risk of esophageal intubations and vomiting amongst all providers.[46]

Airway Adjuncts

There are numerous airway adjuncts to aid difficult or complicated intubations in critically ill patients. The bougie (Eschmann Tracheal Tube Introducer), is a long flexible tubing with an anterior tip angulation (30 degrees) that is inserted through the vocal cords and acts as an introducer for ETT placement via Seldinger-like technique.[47] The bougie helps maintain continuous access to the airway as well as facilitating difficult anterior intubations with partial or even absent views of the vocal cords.[48] While in patients with at least 1 difficult airway characteristic, using an introducer was associated with a 14% increase in first-pass success,[49] however a follow up study did not see this effect when applied to the critically ill patient population.[50] It is important to note that there is a mild learning curve to overcome when using the bougie with an added intubation time of approximately 5-8 seconds.[51,52] When using the bougie as an introducer, preloading the endotracheal tube in similar fashion as a stylet may decrease time to intubation compared to the Seldinger-like technique.[51] This may make the time difference negligible and increase the success rate of intubation.

Flexible fiberoptic bronchoscopy and intubating laryngeal mask airways (LMA) are other forms of airway adjuncts that may be helpful in challenging situations, and for those experienced with their use.[53,54] Flexible fiberoptic bronchoscopy may be beneficial for use in awake intubations when the risk of sedation and paralytic medications are high. Visualization of the airway can be achieved without complete paralysis and can be beneficial in obese patients, airway obstruction, oral or gastrointestinal bleeding, etc.[55] Flexible fiberoptic bronchoscopy has also been found to decrease cervical spine motion during intubation which can be vital in patients with unstable or fragile cervical spines (ie trauma, stenosis, etc).[56] Intubating LMAs provide the opportunity for airway support with blind insertion of the LMA in typical fashion but then can be followed by insertion of an endotracheal tube all the while allowing for ventilation of the patient.[57] Flexible bronchoscopy can also be used with intubating LMAs to allow for ventilation while visualizing the airway with capability to insert an endotracheal tube over the bronchoscope in Seldinger-like technique.[57]

Peri and Post Intubation Period

While intubation is a major life saving treatment, the effects of RSI medications as well as the transition from negative pressure respiration to positive pressure ventilation can have a deleterious effect on patients, especially those who are critically ill. RSI medications are utilized for both airway visualization and patient comfort for which the effects inevitably blunt the often compensatory catecholamine response in patients with critical illness. Approximately 45% of patients undergoing intubation will experience one major peri-intubation adverse event with cardiovascular instability being the most common.[58] These adverse events correlate with patient mortality risk and up to 3% of patients with adverse events will suffer cardiac arrest.[59,60] Critically ill patients often present with unstable

physiology, including respiratory or metabolic acid base disorders, shock states, organ failure, and compromised ability to compensate for these derangements.[61]

Airway management in the critically ill can be complex and difficult. The act of positive pressure ventilation alone causes an increase in intrapulmonary pressure and a decrease in preload and venous return to the heart. Patients who have hypovolemic states or underlying cardiovascular compromise are likely to decompensate by the very act of positive pressure ventilation. Risk factor recognition and preparation are key to help decrease peri-intubation adverse events including cardiac arrest.[60] Strategies such as quick initiation of intravenous fluids for preload dependent states, vasoactive agents for peri-intubation hypotension and bradycardia, and immediate cardiopulmonary resuscitation and defibrillation in the event of fatal arrythmias are among a few ways to support critically ill patients during peri and post-intubation.[62]

The INTUBE study included over 2,700 patients undergoing endotracheal intubation and found that 42% had cardiovascular instability with a majority of these patients receiving propofol for induction.[63] Intravenous fluid bolus and vasopressors that are initiated prior to intubation in all comers has not shown overall reduction in cardiovascular instability. Realistically intravenous fluids should be implemented for those at high risk including critically ill patients. For instance, in a subgroup analysis, intravenous fluid boluses administered before intubation in patients undergoing positive pressure ventilation (NIPPV or bag-valve-mask) showed benefit while there was potential harm when applied to the study group as a whole.[64] In terms of vasopressor support, cardiovascular instability has not been shown to differ between particular vasopressor strategies and should therefore be selected based on patient hemodynamic profiles. Patients with increased pulmonary vascular resistance (restrictive lung disease, acute respiratory distress syndrome, pulmonary hypertension, right heart failure, etc) are prone to hemodynamic collapse once positive pressure ventilation is initiated. These patients may benefit from therapies that can reduce pulmonary vascular resistance and avoid right ventricular preload, and potentially awake intubation.[62,63] On the other hand, patients with left ventricular heart failure, restrictive physiology, septic cardiomyopathy, and hypovolemia may not tolerate a reduction in preload, cardiac contractility, or systemic vascular resistance. Initiation of targeted therapies for these patients may rely upon intravenous fluid administration, ionotropic support, or vasoactive agents that increase systemic vascular resistance.[65] Critically ill patients present with complex physiologic states and thoughtful medication and airway strategies should be implemented to best serve their hemodynamics.

Conclusion

Over the past few decades new advances in airway management have included optimization of pre-oxygenation strategies, rapid sequence induction and paralytic medications, and adjunctive airway tools for optimal visualization and first pass success.[66] With these advances in airway management and adjunctive strategies, surgical airway placement (i.e. cricothyroidotomy, retrograde intubation, sub-mental airway, tracheostomy, etc), typically is required in <1% of select cases.[41,47,67] It is unlikely that there is a single superior and uniform approach to airway management as every patient presents with a different and often complex disease state. Instead, emergency providers should utilize the tools and resources available to best treat the individual patient. These authors believe that utilizing these advanced therapies and approaches may allow for improvement in airway management of critically ill patients.

Conflicts of Interest

On behalf of all the authors, the corresponding author states that the authors declare that they have no competing interests.

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