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EDITORIAL

Best practices in airway management in critically ill adults

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Tracheal intubation is one of the most common procedures performed in the critically ill. In a global study including 2964 critically ill adult patients, at least one major peri-intubation adverse event occurred in 45% of patients, with cardiovascular collapse (43%) and severe hypoxemia (9%) being the most common [1]. Of note, the occurrence of these events was associated with an increased risk of both intensive care unit (ICU) and 28-day mortality [1]. Factors contributing to this high complication rate include the complex environment, the varied experience of the operator, and most importantly, the critical illness itself [2, 3]. Critically ill patients have a *physiologically difficult airway*, defined in a recent global expert consensus Delphi study as one in which the patient's physiological and pathophysiological alterations increase the risk of complications during tracheal intubation and transition to positive pressure ventilation [4, 5]. Airway societies and experts have provided guidance to mitigate the complications that occur during this high-risk procedure [2–6]. This narrative review highlights various strategies to improve the safety and efficacy of tracheal intubation in critically ill adults. Though literature including critically ill patients was reviewed, some papers had mixed populations from ICU, operating room (OR), and emergency settings, which may make the extrapolations difficult between different settings. Future research priorities based on the gaps identified by the authors of this paper have been outlined in Table 1.

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Preparation for tracheal intubation

The MACOCHA score [7], which considers physiological alterations and the experience of the operator, in addition to anatomical difficulty (Supplemental Table 1), is validated for airway assessment in ICU. Human factors influence safe performance of tracheal intubation, with team preparation being paramount to mitigate the risk of complications [5]. Though the benefit of using a pre-intubation checklist to reduce complications has not been established, this may be effective when interventions for physiological optimization are included [8] and when used by less experienced teams.

Respiratory optimization

The use of head-elevated laryngoscopic position (HELP), with the head of the bed elevated to 30 degrees, has been suggested by experts [5]. The posterior portions of the lung become more prone to atelectasis and collapse in the supine position. A head-up position during preoxygenation helps to increase the functional residual capacity (FRC) and thereby decrease the incidence of hypoxemia during tracheal intubation, especially in patients with obesity [5, 9].

Several preoxygenation strategies have been practiced to reduce the incidence of hypoxemia during tracheal intubation: bag-valve mask (self-inflating device), non-invasive ventilation (NIV) which provides positive pressure ventilation, non-rebreather mask (high-concentration oxygen delivery device), or high-flow nasal oxygen (HFNO). Preoxygenation using a facemask (standard oxygen or NIV) needs to be removed during laryngoscopy, while HFNO has the advantage that it can be continued. The PREOXI trial [10] confirms the superiority of NIV over facemask oxygen (either a nonrebreather mask or bag-valve mask device) for preoxygenation, without increased incidence of aspiration. No difference in severe hypoxemia was noted when preoxygenation with NIV or

Table 1 Future research priorities for airway management in critically ill adults

1	Determine the optimal strategy to prevent cardiovascular collapse (using a fluid bolus, or vasopressors or a combination prior to tracheal intubation) during tracheal intubation
2	Determine which vasopressor (ephedrine, phenylephrine, norepinephrine) could be used and how (dose, timing, dilution) to prevent cardiovascular collapse during tracheal intubation
3	Compare the efficacy of NIV, HFNO, combinations of the two and other methods, in different patient populations, clinical settings, and levels of hypoxemia, including the evaluation of long-term effects
4	Evaluate the role of peri-procedural point-of-care ultrasound for the assessment and management of cardiorespiratory compromise during tracheal intubation in the critically ill
5	Evaluate the ideal combination of sedative-hypnotic drugs to enhance the efficacy and safety of tracheal intubation in the critically ill
6	Identify patients that could benefit from the Sellick maneuver performed during rapid sequence induction
7	Assess whether the use of videolaryngoscope compared to direct laryngoscope is associated with fewer episodes of hypoxemia and other complications, in addition to first pass intubation success
8	Assess the impact of individualized protocols for tracheal intubation based on the severity of illness of the patient
9	Assess the role of artificial intelligence to help to apply best practices for tracheal intubation in critically ill patients and assess its efficacy in randomized controlled trials
10	Establish how tracheal intubation in critically ill adults can be performed safely and effectively in resource limited setting

NIV non-invasive ventilation, *HFNO* high flow nasal oxygen

HFNO (continued during laryngoscopy) was compared in hypoxemic patients undergoing tracheal intubation. A trial in patients with acute hypoxemic respiratory failure comparing preoxygenation with NIV versus HFNO (continued during laryngoscopy) did not show any difference in the incidence of severe hypoxemia. However, the subgroup analysis suggested that NIV may be superior to HFNO among patients with moderate to severe hypoxemia [11]. A proof of concept study showed that NIV combined with HFNO was superior to NIV alone in preventing desaturation following intubation of hypoxemic patients in ICU. This needs further evaluation [12]. A systematic review comparing preoxygenation strategies in critically ill adults concluded that NIV or HFNO are superior to facemask oxygen during tracheal intubation and that compared with HFNO, NIV decreases the incidence of hypoxemia during tracheal intubation [13]. These findings suggest that it may be time to abandon the use of conventional facemask oxygen in this high-risk population [14]. In agitated patients, the use of a sub-anesthetic dose of ketamine to facilitate preoxygenation (i.e., delayed sequence intubation) significantly decreases peri-intubation hypoxia [15]. Gentle mask ventilation performed during the apneic phase of a modified rapid sequence intubation (RSI) has been shown to reduce peri-procedural hypoxemia without increasing the incidence of aspiration [16]. Research gaps in the field of respiratory optimization are detailed in Table 1.

Hemodynamic optimization

Considering the high incidence of hemodynamic collapse during the procedure, hemodynamic optimization and monitoring are paramount. However, the precise method of performing hemodynamic optimization is not clear in the literature, and further research is needed (Table 1). The Montpellier intubation protocol, the use of which demonstrated a reduction in intubation-related complications, includes a fluid bolus prior to tracheal intubation, unless contraindicated [8]. This has been validated by another team in an observational study [17]. However, in two randomized trials, administration of a fluid bolus prior to intubation showed no reduction in cardiovascular collapse [18, 19]. Two ongoing international trials (the FLUVA Trial [NCT05318066] and the PREVENTION trial [NCT05014581]) are investigating the effectiveness of pre-emptively administering vasopressors in preventing cardiovascular collapse in critically ill adults undergoing tracheal intubation.

Performing tracheal intubation

A modified RSI technique (administration of rapid-onset sedative hypnotic and a rapid-acting neuromuscular blocking agent, and/or gentle mask ventilation) should be considered to minimize the risk of aspiration [5]. Cricoid pressure (if applied) should be pursued until the tracheal tube is inserted appropriately and the tracheal tube cuff is inflated, as regurgitation may occur with the pressure transmitted to the esophagus. However, it should be released in case of difficulty in glottic visualization [5]. Evidence is lacking to determine which patients could benefit from the use of cricoid pressure (Table 1).

Drugs used for tracheal intubation

The post hoc analysis of the INTUBE study showed that the use of propofol for induction was the only modifiable independent predictor of cardiovascular collapse in these patients [20]. Therefore, drugs with a more stable hemodynamic profile, such as ketamine and etomidate, have

been recommended [5]. The decision to use either of these drugs should be based on individual patient characteristics, contra-indications, side effects of each drug, and local practices [5]. Future studies are required to individualize induction agents used for tracheal intubation in the critically ill (Table 1).

Use of neuromuscular blockade during RSI is associated with greater first-pass intubation success and lesser complications. A study comparing succinylcholine and rocuronium for tracheal intubation in critically ill patients showed no clinically meaningful difference between the two drugs [21]. Succinylcholine should be avoided in patients with skeletal muscle myopathies, known allergy, history of malignant hyperthermia, hyperkalemia, and significant burn injury [5]. There is a dose–response effect of rocuronium; higher doses of at least 1.2 mg/kg are required to produce faster time to optimal intubating conditions [2]. Sugammadex may be used for the rapid reversal of rocuronium in a "*cannot intubate, cannot ventilate*" situation, though the safety data in critically ill patients is limited [5]. However, its role in this situation is extremely limited, as sugammadex may reverse the paralytic, but not the need for intubation, required in most of these patients [22].

Devices used for tracheal intubation

Various tools and strategies can help improve first-pass intubation success and thereby reduce complications. It is now clearly demonstrated that videolaryngoscopy (VL) provides superior intubation conditions over direct laryngoscopy (DL) [23, 24]. The STYLETO (Stylet for orotracheal intubation) trial demonstrated that using a stylet with a tracheal tube during intubation with a DL resulted in a significantly higher first-pass intubation success rate compared to a tracheal tube alone [25]. A study in critically ill adults comparing the use of a tracheal tube with a bougie or a stylet during the first attempt at intubation reported no difference in first-pass intubation success [26]. Taken together, these studies highlight the importance of the routine use of a stylet or a bougie during the first attempt at tracheal intubation. Nevertheless, future research is needed to assess which of these devices may be superior in specific settings (Table 1).

Post procedure care

Tracheal placement of the tube should be confirmed using consistent waveform capnography over at least seven breaths [24]. Chest auscultation, chest X-ray, and/or bronchoscopy are acceptable methods to confirm the optimal depth of the tube in the trachea [5]. A lung protective ventilation strategy, along with the use of sedative infusions, should be employed post intubation [5]. Complications that occur should be managed appropriately.

Complications associated with tracheal intubation in critically ill adults continue to remain high [1]. While evidence supporting the management of patients with a *physiologically difficult airway* is evolving, the implementation of the existing strategies discussed above may help improve patient outcomes.

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