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WHAT'S NEW IN INTENSIVE CARE

What's new in airway management of the critically ill

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Airway management, including tracheal intubation (TI) and tracheostomy constitute the most commonly performed procedures in critically ill patients. Critically ill patients have a 'physiologically difficult' airway, i.e. where the underlying hypoxaemia, hypotension, metabolic acidosis and other pathophysiologic changes substantially increase the risk of complications during TI. In contrast to patients in the operating room, factors such as the emergent nature of airway management, the increased risk of aspiration, variable levels of operator experience, less advanced equipment and complex intubating conditions, pose significant additional challenges during TI in these patients. In addition, a proportion of these critically ill patients will also have 'anatomically' difficult airways, further increasing risk for adverse airway-related outcomes [1].

In the UK 4th National Audit Project report, almost 20% of all major airway-related complications occurred in ICU, leading to death or brain injury in 61% of the cases, compared to 14% during anaesthesia [1]. Failure to use capnography, poor recognition of high-risk airways, poor planning, lack of advanced airway skills and equipment, were major contributing factors [1]. The incidence of cardiac arrest was 2.7% in a retrospective analysis of 1847 TIs from 64 French ICUs. Arterial hypotension and hypoxia prior to TI, lack of preoxygenation, obesity and older age were associated with an increased risk [2]. Recognizing the high risk of airway management in ICU, three guidelines specific to tracheal intubation in ICU were recently published by various international societies, with a focus on strategies to enhance safety during TI [3–5]. We report a brief update of the recent evidence on approaches to decrease the morbidity from airway management in critically ill patients (Table 1).

Preparation for tracheal intubation: a checklist?

Janz and colleagues recently performed the first randomized trial investigating the use of a written checklist prior to TI in ICU compared to usual care [6]. The checklist included 10 recommended preparatory steps to be performed before TI. The effect was modest, with no difference in lowest oxygen saturation and lowest systolic blood pressure from induction up to two minutes after TI between the groups. Unfortunately, the checklist did not include interventions aiming at physiological optimization (e.g. noninvasive ventilation, fluid load, early use of vasopressors), possibly explaining why the checklist did not influence the selected outcomes. Moreover, given the prior significant expertise in participating centers in airway management and the use of checklists for other ICU procedures, a high penetrance of checklist items may have been present in the control group. Nonetheless, a pre-intubation checklist may be more effective in less experienced teams and where the checklist includes interventions to enhance oxygenation and hemodynamic optimization, as observed following the implementation of the ICU intubation bundle aimed at reducing life-threatening complications associated with TI [7].

Preoxygenation and apnoeic oxygenation: utility of high flow nasal cannulae oxygen

Hypoxia is a leading complication of TI. In the last few years, methods to reduce desaturation have been a major part of the research agenda for airway management. In an attempt to increase the safe apnea period, different preoxygenation (i.e. denitrogenation with high-flow oxygen with or without positive pressure ventilation) strategies have been used. During the apnoeic period prior to

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Table 1 Major studies on airway management in the critically ill published in the last 3 years

Study description	Intervention/objective	Outcomes/endpoints	Major findings
Preparation—risk prediction			
Multicenter RCT of adult patients requiring ETI in ICU (Janz et al. [6])	Efficacy of a written, verbally-performed pre-intubation checklist (130 patients) versus no intubation checklist (132 patients)	Primary outcome: composite of lowest SpO_2 and lowest systolic blood pressure Secondary outcomes: life-threatening complications, time and N° of laryngoscopy attempts, ventilator-free days, ICU free-days, in-hospital mortality	There was no difference in median lowest SpO_2 and lowest SBP between the checklist group and usual care. No differences were observed in duration, n° of laryngoscopy attempts or severe complications
Retrospective analysis of prospectively collected data of studies on adult patients requiring ETI in ICU (De Jong et al. [2])	To determine the incidence and factors associated with intubation-related cardiac arrest in critically ill patients requiring ETI in ICU	Primary outcome: intubation-related cardiac arrest Secondary outcomes: cardiac arrest without ROSC, severe and moderate complications, mortality at 28 days	Forty-nine out of 1947 ETIs (2.7%) were followed by cardiac arrest Arterial hypotension (SBP < 90 mm Hg) and hypoxaemia prior to intubation, absence of preoxygenation, overweight/obesity and age more than 75 years old were the five identified independent risk factors for cardiac arrest
Preoxygenation strategies			
Multicenter RCT of adult patients requiring ETI in ICU with a $PaO_2/FiO_2 > 200$ (Guitton et al. [9])	HFNC with 60 L/min and FiO_2 100% (95 patients); BVM with 15 L/min and reservoir (89 patients)	Primary outcome: lowest SpO_2 Secondary outcomes: $SpO_2 < 95$, 90, 80%, severe and moderate adverse events, length of ICU stay, organ failure, duration of ventilation, ventilator-associated pneumonia, mortality at 28 days	No difference in median lowest SpO_2 between HFNC and BVM Severe complications ($SpO_2 < 80\%$, severe hypotension, cardiac arrest) were less frequent in the HFNC group compared to BVM group
Multicenter RCT of adult patients with acute hypoxemic respiratory failure ($PaO_2/FiO_2 \leq 300$) (Frat et al. [10])	Facemask NIV with a PS set to obtain a V_{TE} 6–8 ml/Kg, PEEP 5 cm H_2O and FiO_2 100% (142 patients) HFNC with 60 L/min and FiO_2 100% (171 patients)	Primary outcome: $SpO_2 < 80\%$ Secondary outcomes: lowest SpO_2, difficult intubation, agitation, immediate and late complications	No overall difference in severe hypoxaemia between NIV and HFNC. In patients with moderate-to-severe hypoxaemia ($PaO_2/FiO_2 \leq 200$ mm Hg), severe hypoxaemia occurred less frequently after preoxygenation with NIV than with HFNC. No difference was observed in immediate and late complications
Rapid sequence induction			
Multicenter RCT of adult patients requiring ETI with RSI in ICU (patients at high risk of aspiration excluded) (Casey et al. [12])	BVM during apneic period post induction (199 patients) No ventilation between induction and ETI (202 patients)	Primary outcome: lowest SpO_2 Secondary outcomes: $SpO_2 < 80\%$, oropharyngeal or gastric aspiration, presence of new opacities on chest X-rays < 48 h from ETI	Median lowest SpO_2 was 96% (IQR 87–99%) in the BVM group and 93% (IQR 81–99%) in the no-ventilation group, $p = 0.01$ In the BVM group, 10.9% had an $SpO_2 < 80\%$ vs 22.8% in the no-ventilation group (RR 0.48, 95% CI 0.30–0.77). No difference between groups in operator-reported aspiration (2.5% in the BMV group vs 4% in the no-ventilation group, $p = 0.41$) or new opacities (16.4 in the BVM group vs 14.8 in the no-ventilation, $p = 0.73$)
Device/adjuncts for laryngoscopy			
Meta-analysis of RCT of adult patients requiring intubation in the ICU randomized to either DL or VL (Huang et al. [14])	VL or DL	Primary outcome: first-attempt success Secondary outcomes: duration, glottic visualization (Cormack grade), complications and mortality	VL did not improve first-attempt success rate. Data remained unchanged when the intervention was the Glidescope® VL. VL led to better glottic visualization but not to a faster intubation or a lower incidence of complications
Single center RCT of critically ill adults requiring intubation in the ED with DL (Driver et al. [17])	ETI with bougie (381 patients) ETI with stylet (376 patients)	Primary outcome: first-attempt success in patients with at least 1 difficult airway characteristic Secondary outcomes: first-attempt success in all patients, without hypoxaemia, attempt duration, esophageal intubation, hypoxia	First-attempt intubation success was higher in the bougie group (96%) than in the endotracheal tube + stylet group (82%) (absolute between-group difference 14%; 95% CI 8% to 20). No difference was observed in duration of intubation and incidence of hypoxaemia

BVM bag-valve mask, *CI* confidence interval, *CICO* cannot intubate-cannot oxygenate, *DL* direct laryngoscopy, *ED* emergency department, *HFNC* high-flow nasal cannulae therapy, *ICU* intensive care unit, *IQR* interquartile range, *NIV* noninvasive ventilation, *RCT* randomized controlled trial, *ROSC* return of spontaneous circulation, *RR* relative risk, *RSI* rapid-sequence induction, *SBP* systolic blood pressure, *VL* videolaryngoscopy

intubation, apnoeic oxygenation (i.e. oxygen delivery during the apnea time) strategies have been investigated [8]. The high flow nasal cannulae (HFNC), which can be used to deliver up to 80 L/min of heated and humidified oxygen, have been tested in both settings.

The PROTRACH study investigated the hypothesis that HFNC used for preoxygenation and continued to provide apnoeic oxygenation during tracheal intubation could reduce desaturation compared to bag-valve mask preoxygenation in patients without severe hypoxaemia (PaO_2/FiO_2 ratio $\geq$ 200 mmHg) [9]. Though there was no difference in the primary outcome (the lowest SpO_2 during intubation), patients in the HFNC group experienced a lower incidence of intubation-related complications (including $SpO_2 < 80\%$, severe hypotension and cardiac arrest) [9].

The FLORALI-2 study randomized 313 patients with hypoxic respiratory failure (PaO_2/FiO_2 ratio $\leq$ 300 mmHg) to preoxygenation using non-invasive ventilation (NIV) or HFNC (continued to provide apnoeic oxygenation during tracheal intubation) [10]. There was no difference in the primary outcome which was the occurrence of severe hypoxaemia ($SpO_2 < 80\%$). A beneficial effect of NIV compared to HFNC was observed in patients with moderate to severe hypoxaemia [10]. Jaber et al. [11] in a proof of concept study (OPTINIV trial), found that there were lesser incidences of desaturations when HFNC was added to NIV, as compared to NIV alone, for preoxygenation during TI in critically ill patients.

From the available evidence, NIV seems to be the method of choice for preoxygenation to increase the oxygen reserve, especially in severely hypoxic patients suffering from an increased alveolar–arterial gradient and pulmonary shunt. HFNC oxygen use has shown lesser intubation related complications as compared to bag-valve mask for preoxygenation in patients who are not severely hypoxemic. HFNC oxygen has shown benefit when added to NIV during preoxygenation and continued during TI. However, further studies are needed to strengthen these recommendations.

Rapid sequence induction: a practice change?

Critically ill patients may not be fasted and/or may have slower gastric emptying. Thus, conventionally, a rapid sequence induction (RSI), i.e. administration of rapid onset agents and avoidance of ventilation between induction and intubation, to limit gastric insufflation and pulmonary aspiration, is indicated. However, hypoxaemia during this period is a concern.

In the PREVENT study, patients were randomized to receive mask ventilation or no ventilation between induction and intubation [12]. Patients receiving ventilation experienced lower incidence of severe hypoxaemia compared to controls without suffering from an increased rate of pulmonary aspiration. However, the study was not powered to look at pulmonary aspiration and excluded patients at high aspiration risk (i.e. pregnant women, patients with emesis, hematemesis or hemoptysis). Nevertheless, it further challenges the historic dogma and provides some reassurance for gentle ventilation to limit hypoxia during RSI.

Device selection for intubation

Use of videolaryngoscopes

A meta-analysis comparing direct laryngoscopy (DL) with videolaryngoscopy (VL) for emergency intubation outside the operating room showed higher first pass intubation success rates with VL compared with DL and fewer oesophageal intubations in the subgroup of ICU patients, though not overall success rates. Of concern, the use of VL was associated with more life-threatening complications including arterial hypotension [13]. In two recent meta-analyses of randomized trials, the use of VL did not increase first-attempt intubation success rate in ICU, nor improve outcomes compared with DL [14, 15]. Some studies included in these meta-analyses have shown higher incidence of severe life-threatening complications with VL use. An explanation given for these findings is failure to abort TI attempts when there is a clear laryngeal view using VL, leading to prolonged apnea time and complications [14, 15]. Nevertheless, though recent evidence does not support the routine use of VL for TI in ICU, VL improves glottic visualization as compared to DL and reduces the incidence of oesophageal intubation, making it an important tool for difficult airway management in ICU, especially in expert hands [3, 4]. Future trials will better define the role of VL in ICU, especially with respect to appropriate use of airway adjuncts, optimal patient position, the ideal glottis view required for a successful VL-assisted intubation and they should use adverse outcomes such as severe complications, rather than first pass intubation success rate alone as a primary outcome [15, 16].

Use of a bougie

A recent large randomized study compared the use of a bougie with an tracheal tube and a stylet for TI in the emergency department [17]. The use of a bougie resulted in significantly higher first-attempt intubation success in patients undergoing emergency TI, with at least one difficult airway characteristic [17]. This was a single center study with operators experienced with bougie use. Hence the generalizability of these findings remains unclear. Nevertheless, given their demonstrated utility in different

settings and their low cost, it seems reasonable to suggest that a bougie may be used to facilitate the initial TI in those experienced with its use.

Future directions

Reducing hypoxia and other complications are a priority during airway management in critically ill patients. Thus, interventions aimed at increasing first-pass intubation success (role of VL, bougie etc.) should be integrated with those aiming at optimizing physiology.

An ongoing large international observational study (INTUBE, NCT03616054), will provide data on current incidence of intubation-related complications and the practice of airway management in critically ill patients worldwide. This snapshot of real-world practices may help develop strategies aimed at physiological optimization and intubation-related risk reduction.

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Compliance with ethical standards

Conflicts of interest

Dr. Russotto is the principal investigator of the INTUBE Study (NCT03616054); Prof. Myatra and Prof. Laffey are in the SC of the same study. Authors did not report any other conflict of interest for this paper.

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References

1. Cook TM, Woodall N, Harper J et al (2011) Major complications of airway management in the UK: results of the fourth national audit project of the royal college of anaesthetists and the difficult airway society. Part 2: intensive care and emergency departments. Br J Anaesth 106:632–642. https://doi.org/10.1093/bja/aer059
2. De Jong A, Rolle A, Molinari N et al (2018) Cardiac arrest and mortality related to intubation procedure in critically ill adult patients: a multicenter cohort study. Crit Care Med 46:532–539. https://doi.org/10.1097/CCM.0000000000002925
3. Myatra SN, Ahmed SM, Kundra P et al (2017) Republication: all India difficult airway association 2016 guidelines for tracheal intubation in the intensive care unit. Indian J Crit Care Med 21:146–153. https://doi.org/10.4103/ijccm.IJCCM_57_17
4. Higgs A, McGrath BA, Goddard C et al (2018) Guidelines for the management of tracheal intubation in critically ill adults. Br J Anaesth 120:323–352. https://doi.org/10.1016/j.bja.2017.10.021
5. Quintard H, l'Her E, Pottecher J et al (2017) Intubation and extubation of the ICU patient. Anaesth Crit Care Pain Med 36:327–341. https://doi.org/10.1016/j.accpm.2017.09.001
6. Janz DR, Semler MW, Joffe AM et al (2018) A multicenter randomized trial of a checklist for endotracheal intubation of critically ill adults. Chest 153:816–824. https://doi.org/10.1016/j.chest.2017.08.1163
7. Jaber S, Jung B, Corne P et al (2010) An intervention to decrease complications related to endotracheal intubation in the intensive care unit: a prospective, multiple-center study. Intensive Care Med 36:248–255. https://doi.org/10.1007/s00134-009-1717-8
8. Russotto V, Cortegiani A, Raineri SM et al (2017) Respiratory support techniques to avoid desaturation in critically ill patients requiring endotracheal intubation: a systematic review and meta-analysis. J Crit Care 41:98–106. https://doi.org/10.1016/j.jcrc.2017.05.003
9. Guitton C, Ehrmann S, Volteau C et al (2019) Nasal high-flow preoxygenation for endotracheal intubation in the critically ill patient: a randomized clinical trial. Intensive Care Med 45:447–458. https://doi.org/10.1007/s00134-019-05529-w
10. Frat J-P, Ricard J-D, Quenot J-P et al (2019) Non-invasive ventilation versus high-flow nasal cannula oxygen therapy with apnoeic oxygenation for preoxygenation before intubation of patients with acute hypoxaemic respiratory failure: a randomised, multicentre, open-label trial. Lancet Respir Med 7:303–312. https://doi.org/10.1016/S2213-2600(19)30048-7
11. Jaber S, Monnin M, Girard M et al (2016) Apnoeic oxygenation via high-flow nasal cannula oxygen combined with non-invasive ventilation preoxygenation for intubation in hypoxaemic patients in the intensive care unit: the single-centre, blinded, randomised controlled OPTINIV trial. Intensive Care Med 42:1877–1887. https://doi.org/10.1007/s00134-016-4588-9
12. Casey JD, Janz DR, Russell DW et al (2019) Bag-mask ventilation during tracheal intubation of critically ill adults. N Engl J Med 380:811–821. https://doi.org/10.1056/NEJMoa1812405
13. Arulkumaran N, Lowe J, Ions R et al (2018) Videolaryngoscopy versus direct laryngoscopy for emergency orotracheal intubation outside the operating room: a systematic review and meta-analysis. Br J Anaesth 120:712–724. https://doi.org/10.1016/j.bja.2017.12.041
14. Huang H-B, Peng J-M, Xu B et al (2017) Video laryngoscopy for endotracheal intubation of critically ill adults: a systemic review and meta-analysis. Chest 152:510–517. https://doi.org/10.1016/j.chest.2017.06.012
15. Jiang J, Ma D, Li B et al (2017) Video laryngoscopy does not improve the intubation outcomes in emergency and critical patients—a systematic review and meta-analysis of randomized controlled trials. Crit Care 21:288. https://doi.org/10.1186/s13054-017-1885-9
16. Jaber S, De Jong A, Pelosi P et al (2019) Videolaryngoscopy in critically ill patients. Crit Care 23:221–227. https://doi.org/10.1186/s13054-019-2487-5
17. Driver BE, Prekker ME, Klein LR et al (2018) Effect of use of a bougie vs endotracheal tube and stylet on first-attempt intubation success among patients with difficult airways undergoing emergency intubation: a randomized clinical trial. JAMA 319:2179–2189. https://doi.org/10.1001/jama.2018.6496