

We are IntechOpen, the world's leading publisher of Open Access books Built by scientists, for scientists

6,900

Open access books available

186,000

International authors and editors

200M

Downloads

Our authors are among the

154

Countries delivered to

TOP 1%

most cited scientists

12.2%

Contributors from top 500 universities



WEB OF SCIENCE™

Selection of our books indexed in the Book Citation Index
in Web of Science™ Core Collection (BKCI)

Interested in publishing with us?
Contact book.department@intechopen.com

Numbers displayed above are based on latest data collected.
For more information visit www.intechopen.com



Airway Management in Critical Settings

EL Sayed Elkarta and Magdy Eldegwy

Abstract

Airway management continues to be a challenging task for healthcare practitioners and when it comes to critical settings; it carries more challenges even for the skilled persons. Critical settings could be in fact of suits; where intervention takes place, equipment or practitioners taking care of airway management. Critically ill patients with multiple comorbidities, increasing oxygen demand and high respiratory work; that may require elective airway securing. Various protocols, guidelines and recommendations advocated for this task with the prospects of less hemodynamic alteration and prevention of pulmonary aspiration. In the former, starting oxygen therapy for all critical patients on admission was a routine following the concept; if some is good, more must be better. Nowadays excess oxygen may be unfavorable in some acute critical conditions e.g. ischemic strokes, post-acute myocardial infarction and those with hypercapnic respiratory failure. However, still high flow inspired oxygen concentration is the protocol until they are stable then its reduction to reach the targeted arterial oxygen saturation. Oxygen devices used for oxygen delivery are plenty and its selection depends on the many factors; airway patency, patient's conscious level and compliance, and assessment of gas exchange based on arterial blood sample which is recommended for all critically ill patients. Early prompt evaluation of the airway and assessment of gas exchange using arterial blood sample analysis is crucial in all critically ill patients to guide for subsequent oxygen supply and whether the patient needs ventilatory support or not. This chapter will focus on airway management, oxygen therapy and types of ventilatory support required for adult critically ill patients, while other situations' airway management's tools and skills will be discussed in another ones.

Keywords: airway, management, critical, hemodynamic, hypoxemia, guidelines, FONA

1. Introduction

Airway patency is crucial and vital for maintenance of life occurs naturally in the awake and conscious individuals or can be accomplished artificially in those becoming unable to maintain it. Incapacity of this might be intentional; as in medical procedures requiring deep sedation and/or general anesthesia or in pathological conditions; where there is an alteration in sensorium or elective airway protection needed.

Airway management is defined as an intervention using a technique, maneuver or a device to keep its patency, consequently its normal physiological functions have been achieved; providing oxygen and removing carbon dioxide.

Critical illness is a clinical condition belong to a group of medical situations sharing the need of intensive care unit (ICU) admission and have either single or multiple organ dysfunction. Critically ill patients showing different gradations of snags to maintain the airway and subsequently derangement of aerobic metabolism exists. Optimization of oxygen supply is needed, as dramatic rise of both work of breathing and oxygen demand exist.

Hypoxemia is a medical condition where the partial pressure of oxygen in the arterial blood (P_aO_2) is lower than normal. A P_aO_2 value of less than 60 mmHg in normal individuals with healthy lungs; corresponds to arterial oxygen saturation (SpO_2) of 90%, is used as a cut point for hypoxemia treatment initiation. There are many causes and mechanisms of hypoxemia which required management via oxygen administration. Critically ill patients commonly showing hypoxemic status on the time of admission and oxygen supplementation should be considered in all with high flow delivery system (15 L/min) until becoming stable then reduction of inspired oxygen concentration (FIO_2) to achieve a target of SpO_2 of 94–98% or 88–92% for patients with risk of hypercapnic respiratory failure [1].

1.1 Physiological consideration

Airway is the natural passages of the airflow, inaugurated by nose and mouth downwards to the alveoli in the lungs, where the gas exchange takes place involuntary. Airway patency is mandatory for life and it's the responsibility of pharyngeal-laryngeal muscles tonic control and muco-ciliary system's clearance of mucus and foreign particles.

The airflow via the airway is intermittent and biphasic; inwards during inspiration and outwards during expiration. The work of breathing is a potential energy stored in the lung tissues during inspiration that exists by the work of overcoming the elastic forces and resistance in the airway to be enough for subsequent expiration. In compliant, healthy lung this work of breathing does not consume a portion of the body's energy needs and its daily fraction is less than 3% of total body energy requirement [2].

Impaired consciousness, associated cervical spine trauma, burns and pulmonary shunt causing rapid desaturation and impedes preoxygenation. Besides, limited time for airway management before life-threatening hypoxia, hemodynamically (HD) unstable, imminent risk of collapse before intubation, tricky standard induction drugs effects provoke time pressure environment.

Cessation of the desirable airflow in critically ill patients could be due to a variety of reasons, foremost of those is the airway obstruction. Airway obstruction might occur at any, upper parts; due to foreign body, mucus, secretions, blood and decreased sensorium or lower parts; due to aspiration, infection and spasm of bronchial muscles. Different maneuvers and devices used to eliminate the airway obstruction thus maintenance of airflow will be gained.

Airway management in critically ill patient aimed for:

1. Improving the oxygenation.
2. Airway protection and prevention of pulmonary aspiration.
3. Adjunct for procedures; diagnostic e.g. bronchoscopy or therapeutic e.g. banding of bleeding esophageal varices.
4. Relieve the distress of dyspnea.

5. Reduce the work of breathing.
6. Improve CO₂ clearance.
7. Altered sensorium, required airway protection.
8. Others in ICU.

1.2 Anatomical consideration

Critical illness and its management protocols might hinder the airway anatomy, fluid resuscitation and capillary leak makes the airway edematous and distorted. Furthermore, the patient demography, body mass index (BMI), associated neurological and cardiopulmonary comorbidities, and the indication of ICU admission contribute to anatomical difficulties.

1.3 Devices of oxygen delivery

Oxygen (O₂); is an inert gas essential for life, being inspired through the airway and transported via the lungs towards the blood to be used in cellular respiration and delivery of energy needed for body metabolism. Human body uptake of oxygen in concentration of 20.95% from air by natural airways; nose and mouth, transported down along the conductive airways to be resting in the alveoli where the gas exchange happening. Physiological and pathological conditions required an increased FIO₂ to meet the body oxygen requirement and its high demand. Devices are designed to facilitate oxygen delivery from artificial oxygen sources in correspond to the target of FIO₂, patient's breathing effort and patient's device compliance [3].

All critically ill patients must have high-flow oxygen delivery device (15 L/min), until stable status achieved, then oxygen requirement could be individually determined depending on the existing pathology. Patient's breathing effort is the primary determinant for the oxygen delivery device selection. Critically ill patients might be one of two groups; spontaneous breathing group or assisted ventilation one and each group has a preference in oxygen delivery system [4].

1.3.1 Spontaneous- breathing group

Patients with breathing effort requiring O₂ delivering device matched for their breathing power (**Table 1**).

	O ₂ flow rate (L/min)	FIO ₂	Example
Fixed-Performance Devices	2 - 15	Unknown; depend on patient's effort and O ₂ flow rate	Simple face mask, face mask with reservoir bag, nasal cannula. (Figure 1)
Variable- Performance Devices	High, up to 45	Well-known, fixed.	All obey a principle of high airflow O ₂ enrichment (HAFOE). (Figure 2)

Table 1.
Oxygen delivery devices [3].

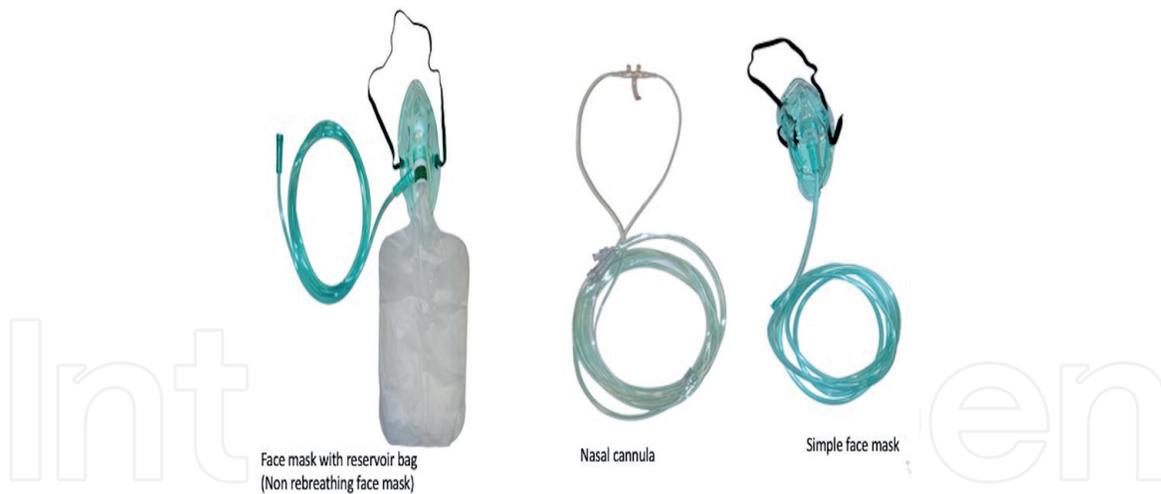


Figure 1.
Oxygen delivery devices (simple face mask with reservoir bag & nasal cannula).



Figure 2.
Oxygen delivery devices (HAFOW).



Figure 3.
Oxygen delivery devices. (bag-mask with self-inflating reservoir bag).

1.3.2 Assisted ventilation group

In this group of critically ill patients, failure to maintain oxygenation and/or ventilation despite an increase in FIO₂ or development of apnea and indicated mechanical ventilation (MV), airway supporting device might be perpetual or temporary as a bridge till the steady one is fixed. Noninvasive positive pressure ventilation (NIPPV), could have both properties as it might be a tie till improvement or securing definitive airway securing device suitable for MV.

Bag-mask with self-inflating reservoir bag; (**Figure 3**) is considered the simplest and commonest O₂ delivery device used in critically ill patients for oxygenation until an airway securing device fixed. It provides FIO₂ close to 100% while the only O₂ delivery device able to provide 100% FIO₂ is the anesthetic breathing system.

2. Airway management in ICU

Airway management in ICU is unlike that carried out in operation theater (OT) and higher in its complications; brain damage and death, and most of it is done on urgent and emergency basis in lack of experienced airway management professionals. In addition; critically ill patients showing limited cardiopulmonary reserve, this increases their risk of hypoxemia and hypotension upon exposure to airway management medications. Subsequently, tracheal intubation for those categories of patients could be life-threatening condition; up to 40% of patients are associated with increase in complication rates of hypoxemia (25%) [5] and hypotension (10–25%) [6], arrhythmia, cardiac arrest and death [7] upon exposure to airway stimulation or pharmacological agents used for it.

Incapacity to perform tracheal intubation at the first attempt “first pass success” has higher risk than that in OT and occurs in 30% of ICU intubations [8]. Many factors contribute to that; lack of competent and expert professional for intubation, patient’s factors and pharmacological agents’ dosage choices. This came with the conclusion of Fourth National Audit Project (NAP4), as it showed around 25% of airway management done in ICU & ED are associated with major adverse effects mostly due to the aforementioned factors [9]. Moreover, equipment unavailability, unfamiliarity and inadequate planning resulting in more stressful environment and subsequently delay in airway management with increasing morbidity and mortality.

ICU settings are not suitably planned for airway management due to several reasons. Limited access to the patient as the bed space is crowded by monitoring, ventilator and other equipment, (**Figure 4**) in addition of the ICU bed is less maneuverable compared to the OT table with unavailability of advanced airway management equipment making it more challenging. Moreover, varying team members of multi-professional backgrounds with non-enough time, experience, accompanying medical devices (collars, masks) and sensorium alteration lead to improper airway assessment beside and inability to ensure adequate preoxygenation necessary to avoid the hypoxia during airway instrumentation. Moreover, unavailability of trained assistance such as anesthesia nurse or technician and lack of structured airway management for ICU staff.

Communication and proper documentation of the airway assessment and its management throughout different hospital facilities is crucial and it might affect the workflow performance. Checklist is the best method of communication among the healthcare professionals from different medical background. Equipment, medications preparation checklist and proper assignment of human forces could make the airway management scenario less stressful and empower its success among critically ill patients.



Figure 4. ICU bed vs. OT space (showed crowding with monitoring, equipment and ventilators).

Quite few challenges could be integrated in airway management for ICU adults, so we can wrap up the considerations and specific precautions that must be accomplish making it less pressure and successfully performed procedure (Table 2).

2.1 Pre-intervention stage

Thorough clinical assessment and prediction of threats that may limit the success of airway management of critically ill patients could be addressed in this time. Also, optimization of all factors; position, preparation and preoxygenation, accentuates the accomplishment of proper airway management intervention.

2.1.1 Airway assessment challenges

Not only thorough assessment of the airway in critically ill patient is vital for successful and safe management but it is unique and carries challenges as compared to that done for patients undergoing daily elective or emergency airway management. Varieties airway assessment modalities, techniques and scoring system had been proposed to allow its safe and easy practice management. Despite the anesthesiologists' or intensivists' predictions of anticipated airway difficulties are a strong diagnostic modality with high positive ratio, but the high proportion of unanticipated difficult endotracheal intubation and its low positive predictive values limits its reliability as a diagnostic test in medical practice [9].

Moreover, the proposed airway assessment scales vary from the simple, that often fail to address the many factors associated with a difficult airway, to the complex, which are impractical as a clinical tool. None have been shown to be accurate in predicting airway management problems, and none have been assessed in the ED setting [10].

NAP4 reports identified frequent airway management failure rate and the high-risk airway patient's identification was not managed through an appropriate airway management approach [9].

Standard airway assessment in critically ill patients is usually unfeasible and difficult to be done especially in those dependent on oxygen delivery devices; face mask or nasal cannula, to avoid hypoxia and provide adequate preoxygenation. The only validated airway assessment scoring system reliable for critically ill patients is the MACOCHA score

Challenge	Consideration	Precaution
ICU environment	ICU space;	• Ideal staff positioning
	Equipment;	• Standard airway trolley availability • Advanced airway; VL, FOB, Bougie available
	Team member;	• Team members briefing and specific task assignment
Patient-related	Physiological;	• HO instability
		• Pulmonary shunt
		• Limited reserve & time for airway management
	Anatomical;	Anticipation and plan for failure.
	Difficult airways;	• Recognition and readiness for difficulties. • MACOCHA score use. • Reduce number of attempts. • Appropriate induction medications, NMBS is routine. • Plan for failure. • Consider FONA.
		Urgency;
	Pharmacological agents;	• Ketamine is recommended. • Avoid over sedation. • Routine use of NMBS. • Consider induction time longer than traditional.
Aspiration risk;	• Modified RSI with cricoid pressure or DSI. • Head-up position.	
Postintubation care	Red flag recognition;	• ETT obstruction, displacement. • Ventilators mechanics and Monitoring: ETT related.

Abbreviations definition; **VL:** video-laryngoscope. **FOB:** fiberoptics laryngoscope. **MACOCHA:** Mallampati score, Apnea syndrome, Cervical spine limitation, Opening mouth, Coma, Hypoxia, Anesthesiologist non-trained. **FONA:** front of neck airway. **NMBS:** neuromuscular blockers. **RSI:** rapid sequence induction. **DSI:** delayed sequence induction

Table 2.
 ICU airway management challenges, considerations and precautions.

(**Table 3**) [11]. It has the advantage of being created with easy identifiable and clinically appropriate variables. Additionally, its used objectives are close to those identified in OT and include risk factors associated with difficult tracheal intubation [12]. Considering any investigations of the airway that already done; such as chest x-ray, CT scan and 3D and Virtual Endoscopy (VE) could be helpful in airway evaluation and might be derive the plan for airway management in critically ill patients [13].

It's recommended to define the cricothyroid membrane for possible front of neck airway (FONA) as a strategy of a plan for failure. This could be done by manual palpation; laryngeal handshake technique [14] (**Figure 5**) or using ultrasound that is accurately defining cricothyroid membrane site, measurements and surrounding structures such as thyroid gland and its vessels [15].

2.1.2 Preparation and preoxygenation challenges

Formerly it's mentioned that; checklist, proper communication, documentation and team briefing with specific task assignment is a key for successful airway management in critical settings. Standard pre-intubation checklist has been developed via Difficult Airway Society (DAS), Intensive Care Society (ICS), Faculty of Intensive Care Medicine (FICM) and Royal College of Anesthetists (RCoA), United Kingdom solving this high-pressure situation (**Figure 6**).

Efficient preoxygenation with end-tidal oxygen concentration of more than 85% is the target [16] must be done in parallel to assessment and preparation. Traditional techniques are somewhat doing this task [17] and the choice of oxygen delivery device depends on the patient's comfort, device availability and the indication for intervention. Although use FIO₂ of 100% with high flow rate; 10–15 L/min

Factors		Points
Factors related to patient	Mallampati score III or IV	5
	Obstructive sleep apnea syndrome (OSA)	2
	Reduced mobility of cervical spine.	2
	Limited mouth opening <3cm.	1
Factors related to pathology	Coma	1
	Sever hypoxemia (<80%)	1
Factors related to operator		1
Total:		12

Abbreviations definition: MACOCHA= Mallampati score III or IV, Apnea syndrome, Cervical spine limitation, Opening mouth <3cm, Coma, Hypoxia, Anesthesiologist non-trained.
Score: 0-12 =easy; 12=difficult.

Table 3.
MACOCHA score [11].



Figure 5.
Laryngeal handshake technique.

intensive care society **intubation Checklist : critically ill adults – to be done with whole team present.** **The Faculty of Intensive Care Medicine** **RCOA**

Prepare the patient	Prepare the equipment	Prepare the team	Prepare for difficulty
<ul style="list-style-type: none"> <input type="checkbox"/> Reliable IV / IO access <input type="checkbox"/> Optimise position <ul style="list-style-type: none"> <input type="checkbox"/> Sit-up? <input type="checkbox"/> Mattress hard <input type="checkbox"/> Airway assessment <ul style="list-style-type: none"> <input type="checkbox"/> Identify cricothyroid membrane <input type="checkbox"/> Awake intubation option? <input type="checkbox"/> Optimal preoxygenation <ul style="list-style-type: none"> <input type="checkbox"/> 3 mins or $\text{EtO}_2 > 85\%$ <input type="checkbox"/> Consider CPAP / NIV <input type="checkbox"/> Nasal O_2 <input type="checkbox"/> Optimise patient state <ul style="list-style-type: none"> <input type="checkbox"/> Fluid / pressor/ inotrope <input type="checkbox"/> Aspirate NG tube <input type="checkbox"/> Delayed sequence induction <input type="checkbox"/> Allergies? <ul style="list-style-type: none"> <input type="checkbox"/> ↑ Potassium risk? - avoid suxamethonium 	<ul style="list-style-type: none"> <input type="checkbox"/> Apply monitors <ul style="list-style-type: none"> <input type="checkbox"/> SpO_2 / waveform ETCO_2 / ECG / BP <input type="checkbox"/> Check equipment <ul style="list-style-type: none"> <input type="checkbox"/> Tracheal tubes x 2 - cuffs checked <input type="checkbox"/> Direct laryngoscopes x 2 <input type="checkbox"/> Videolaryngoscope <input type="checkbox"/> Bougie / stylet <input type="checkbox"/> Working suction <input type="checkbox"/> Supraglottic airways <input type="checkbox"/> Guedel / nasal airways <input type="checkbox"/> Flexible scope / Aintree <input type="checkbox"/> FONA set <input type="checkbox"/> Check drugs <ul style="list-style-type: none"> <input type="checkbox"/> Consider ketamine <input type="checkbox"/> Relaxant <input type="checkbox"/> Pressor / inotrope <input type="checkbox"/> Maintenance sedation 	<ul style="list-style-type: none"> <input type="checkbox"/> Allocate roles <small>One person may have more than one role.</small> <ul style="list-style-type: none"> <input type="checkbox"/> Team Leader <input type="checkbox"/> 1st Intubator <input type="checkbox"/> 2nd Intubator <input type="checkbox"/> Cricoid force <input type="checkbox"/> Intubator's assistant <input type="checkbox"/> Drugs <input type="checkbox"/> Monitoring patient <input type="checkbox"/> Runner <input type="checkbox"/> MILS (if indicated) <input type="checkbox"/> Who will perform FONA? <input type="checkbox"/> Who do we call for help? <input type="checkbox"/> Who is noting the time? 	<ul style="list-style-type: none"> <input type="checkbox"/> Can we wake the patient if intubation fails? <input type="checkbox"/> Verbalise "Airway Plan is:" <ul style="list-style-type: none"> <input type="checkbox"/> Plan A: Drugs & laryngoscopy <input type="checkbox"/> Plan B/C: Supraglottic airway Face-mask Fibreoptic intubation via supraglottic airway <input type="checkbox"/> Plan D: FONA Scalpel-bougie-tube <input type="checkbox"/> Does anyone have questions or concerns?

Text

Figure 6.
 Pre-management preparation; patient, equipment, team assignment.

in a tight-sealed facemask for 3 minutes could be enough in intact spontaneously breathing derive [18] but the use of simple face mask even with reservoir bag is not recommended [19]. Moreover, non-invasive positive pressure ventilation (NIPPV) and continuous positive pressure ventilation (CPAP) could be alternatives for pre-oxygenation in seriously hypoxic patients resulting in improved oxygenation and prevention of atelectasis associated with FIO_2 of 100% via supporting the minute volume ventilation (MVV) [20].

High flow nasal oxygenation (HFNO) between 30 and 70 L/min is a suitable method for preoxygenation that showed safety to extend the safe apnea time during airway instrumentation and effectiveness when combined with NIPPV use [21]. Not only, continuous positive airway pressure (CPAP) delivery with a tight-sealed facemask of 5–10 cm H_2O is recommended for preoxygenation, but also, the use of nasal oxygen with a flow of 5 L/min throughout airway management [19] and might be achieved by NIPPV especially in patients with respiratory failure [20].

Plan for failure must be the strategy of airway management planning, allowing logical and prepared expectations for different scenarios that might occur during the procedure. The guidelines resulted from collaborations of DAS/ICS/FICM/RCoA in United Kingdom with the aim of providing structured, standard and systematic approach of airway management in critically ill patients with the concern of not being a replacement of clinical judgment but rather an organizational and individual framework for clinical practice preparation and health care professionals training [19] (**Figure 7**).

Providing the patient's comfort, upper airway patency, optimizing functional residual capacity and decreasing aspiration risk; sniffing position is desirable as an initial position for airway management in critical settings, [22] while titration of bed head-up if cervical spine injury was suspected or confirmed [22, 23] and with prevalence of obesity among population, ramping position could be an alternative [24].

All airway management in critical settings must be carried out in presence of standard ASA monitoring; electrocardiogram (ECG)/heart rate (HR), non-invasive blood pressure (NIBP), pulse oximetry with oxygen saturation (SPO_2), end-tidal carbon dioxide (EtCO_2) [25]. Invasive blood pressure (IBP) is desirable either vasopressors in-use or HD instability is most likely expected and end-tidal oxygen concentration (EtO_2) monitoring; if available.

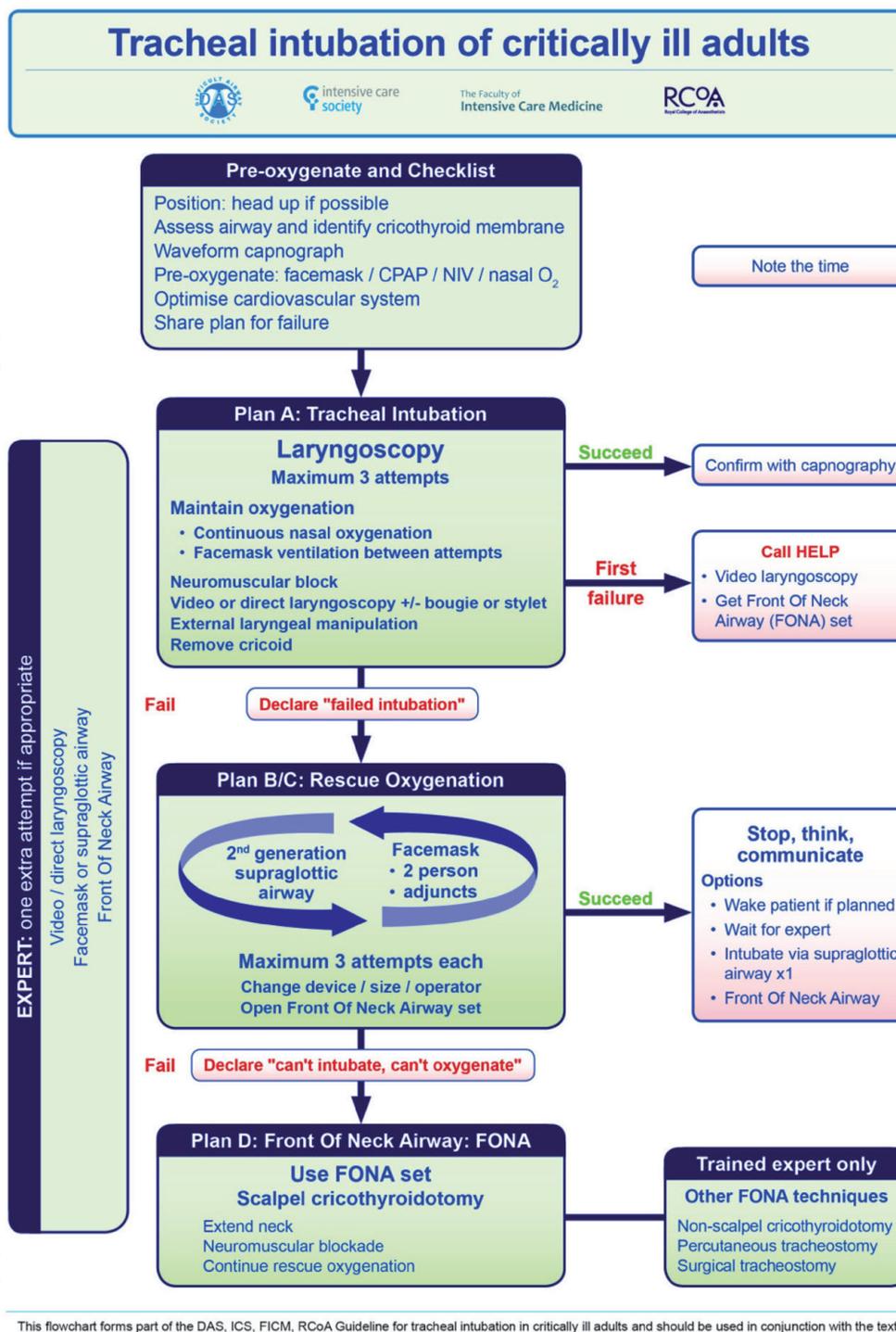


Figure 7. DAS/ICS/FICM/RCoA guidelines for ETI in critically ill patients.

2.1.3 Anesthesia induction and pharmacological considerations

Hypnosis, analgesia and skeletal muscle relaxation is a triad to commence general anesthesia required for airway management and instrumentation. A variety of pharmacological agents are described to achieve this task with specific considerations in dosing titration, delayed onset and extended effect duration.

Airway management of critically ill patients is mostly carried out in ICU while the risk to be done in non-ICU suites still considerable. Non-ICU suites include pre-hospital area, emergency department, radiology department and inpatient ward which carry the risk of difficulty and hence increase in adverse consequences of airway management, that will be discussed separately in corresponding chapters.

There are many factors recommended to reach the optimal airway management in critically ill patients including; intravenous induction agents, use of fast onset neuromuscular blocking agent (NMBA), precautions against pulmonary aspiration, laryngoscopic techniques aimed at first-pass success, and confirmation of successful tracheal intubation by waveform capnography.

Rapid sequence induction and intubation (RSII) is a technique commonly used to protect the airway against gastric contents aspiration and modified to be implemented in some clinical circumstances. A classic RSII consists of oxygen administration, application of cricoid pressure, and the avoidance of mask ventilation before insertion of an endotracheal tube (ETT) for airway securement [26].

A modified RSII in comparison to a classic RSII is to attempt for lung ventilation using positive-pressure ventilation via a facemask [27] before airway securement by ETT.

Delayed sequence intubation (DSI) seems to be safe, effective and could offer an alternative of rapid sequence induction in patients requiring emergency airway management who cannot tolerate preoxygenation or peri-intubation procedures [28]. The ideal DSI induction agent is Ketamine as it preserves airway reflexes and respiratory drive permitting preoxygenation and procedural sedation. DSI technique steps are; ensure the patient has a patent airway, place standard nasal cannula at 5 liters/min in awake patient and increases to 15 liters/min in unconscious one prior to placement of the preoxygenation device. Preoxygenation device choices based on the patient's SpO₂: if SpO₂ > 95% use bag-valve-mask (BVM) with PEEP valve and a good seal at 15 L/min O₂, or non-rebreather (NRB) mask and a good seal at 15 L/min O₂ (or more) while SpO₂ < 95%: use BVM with PEEP valve and a good seal and preoxygenate for at least 3 minutes [19].

2.1.3.1 Induction agents

Choice of induction drug is according to hemodynamic status of the patient; Ketamine is increasingly favored in most circumstances [29]. Administration of a rapidly acting opioids enables lower doses of hypnotics to be used, maintaining cardiovascular stability and minimizing changes of intracranial pressure.

Etomidate as an induction agent is not a first line for intubation in the critically ill patients because the other induction agents have been successfully used without risk of adrenal suppression. Its relative value of short-term hemodynamic stability that is accompanied by a potential adverse effect of adrenal suppression making its use as an anesthetic induction agent in critically ill patients is controversial, although it provides excellent intubating conditions [30]. Another meta-analysis also investigating non-intubation-related adverse effects of Etomidate in critically ill patients stated that its use is not worsening of mortality, organ dysfunction or resource utilization, even if it's adverse effects on adrenal gland function [31]. It's found that hypotension was more prevalent in patients receiving Etomidate compared with Ketamine in the first 24 hours after intubation and subsequent mechanical ventilation [32].

Moreover, Propofol has temporary hypotension episodes as compared to Etomidate, but there is no difference in patients requiring vasopressors after 24 hours [33]. Propofol and Ketamine mixture may have an improved hemodynamic profile compared with Etomidate. Few studies evaluated Etomidate versus Ketamine, finding no difference between them [34].

Dexmedetomidine, Remifentanil and Droperidol have been suggested as induction agents for DSI, but these agents do not have the same pattern of Ketamine as rapid onset, preservation of airway reflexes, intact respiratory drive and safety profile. Fentanyl have a significant sedative effect in addition to analgesia, that may be helpful when titrated to the desirable effect and to avoid over sedation.

NMBA improves intubating conditions, facemask ventilation, nasogastric tube insertion hence, reduction in the number of intubations attempts and optimizing chest wall compliance [35]. Succinylcholine has many side-effects including life-threatening hyperkalemia and its short duration of action can be spared for difficult intubation scenarios. Rocuronium could be the choice in the critically ill patients, providing similar intubating conditions to Succinylcholine and can be antagonized using Sugammadex [36].

Graded sedation intubation without use of NMBA has also been proposed and clinically considered for technique of choice of airway management in critically ill patients [37].

2.2 Intervention stage

This is the subsequent stage, that follows patient's optimization achieved through concomitant preoxygenation, positioning and preparation of staff, equipment and medications. It is a highly stressful time and must be carried out in a strictly controlled and strategic manner.

Current guidelines state four main routes or plans as standard practice and should be done in sequence. From practical point, we believe that algorithm might be modified or interchanged according to the given circumstances, such as in ED and prehospital critical settings, health care professionals could go for plan B/C straight away bypassing plan A because of limited facilities and unsuitable environment that mandate minimal airway manipulation with accomplishment of securing airway patency, proper oxygenation and/or ventilation.

2.2.1 Plan A

Plan A stresses on maintenance of oxygenation either via continuous nasal cannula or interrupted facemask application between laryngoscopic attempts and allowing enough time for desirable effect of pharmacological agents, laryngoscopy attempts using direct (DL) or video-laryngoscope (VL).

With a maximum of three trials, confirmed endotracheal intubation (ENI) through capnography with waveform trace and direct visualization of ETT pass beyond the vocal cords, the call for help of the appropriate help once failed first attempt is a must. Absence of wave trace capnography is a confirmation of failed ETI after exclusion of other causes such as ETT obstruction, pulmonary edema and cardiac arrest. Chest auscultation and its rise during inspiration are rarely used as indicator for successful ETI in critically ill patients [38].

First attempt of ETI, must be done by the most trained, proficient available and must have all team support and consideration of manoeuvres or manipulations with the aim of improving laryngoscopy is recommended after failed first attempt [19]. Operator replacement and equipment change; use of a different blade, addition of others; bougie and external laryngeal manipulation might be reasonable and helpful.

Despite of fulfilling all the available recourses to achieve an optimal laryngoscopic view, with failure of the ETI attempts, either three done or not, the team leader must swiftly proceed to the next airway management plan. DL is the standard use in ETI during daily clinical practice hence its use experience is granted. On the other hand, VL should be in preparation for difficult situation; MACOCHA score > 3 [11] and ensure its availability for critically ill patient management. DL versus VL is the choice of the professionals involved in the airway management scenario and could be the device selected for first attempt according to the institutional policy and training preferences [39].

2.2.2 Plan B/C: (backup plan)

Critically ill patients' lifesaving by maintaining oxygenation during airway management is the priority and failed ETI [8] in the preceding plan A could result in severe hypoxemia [6, 40] that has several serious consequences. It's the responsibility of the team leader to ensure maintenance of adequate oxygenation throughout the stages of airway management. ETT considered as a standard and definitive airway securing device while alternatives used to provide oxygenation in scenarios of failed ETI such as supraglottic airway (SGA) devices and facemask ventilation device.

SGA is considered as a plan B rescue device which consist of variety of devices used for the same purpose; securing upper airway patency that does not require long experience. Facemask ventilation used as a plan C with the purpose of providing O₂ till an alternative being fixed. DAS/ICS/FICM/RCoA guidelines use SGA (plan B) and facemask ventilation (plan C) alternatively to ensure oxygenation after plan A failure confirmation with maximum three turn attempts [19].

Second-generation laryngeal mask airways (LMA) not only possess a design of providing oxygenation, reduce the aspiration risk and conduit for fiberoptic intubation (FOI) [40], but also, promising successful performance in critical areas have been reported [41] so, it's the model of SGA devices to be considered in standard practice and should be available in the difficult airway management trolley. Provision of oxygenation, airway securing, avoidance of aspiration with minimal airway trauma, constantly remain the goals throughout the intervention and subsequent plan to awake patient, wait for airway expert, Fiberoptic Intubation (FOI) through LMA attempt for once or proceed to FONA remains the area of discussion among the airway management team [19].

Basically, it's not recommended to proceed for blind ETI via LMA, [42] on the other hand, FOB accessibility in ICU should be granted [14, 43]. There are alternatives to perform LMA/FOI-guided either using small ETT 6.0 mm inner diameter mounted over the FOB to be advanced through LMA or using Aintree intubation catheter (Cook Medical, Bloomington, IN, USA), that permits ETT > 7.0 mm inner diameter without interruption of oxygenation. Blind ETI with use of either gum elastic bougie or tube exchange catheter (Frova catheter; Cook Medical, Bloomington, IN, USA) is not advisable in critically ill patients as it's associated with tracheal injury, pharyngeal perforation, bronchial bleeding and accused for subsequent positive pressure ventilation-related pneumomediastinum [44].

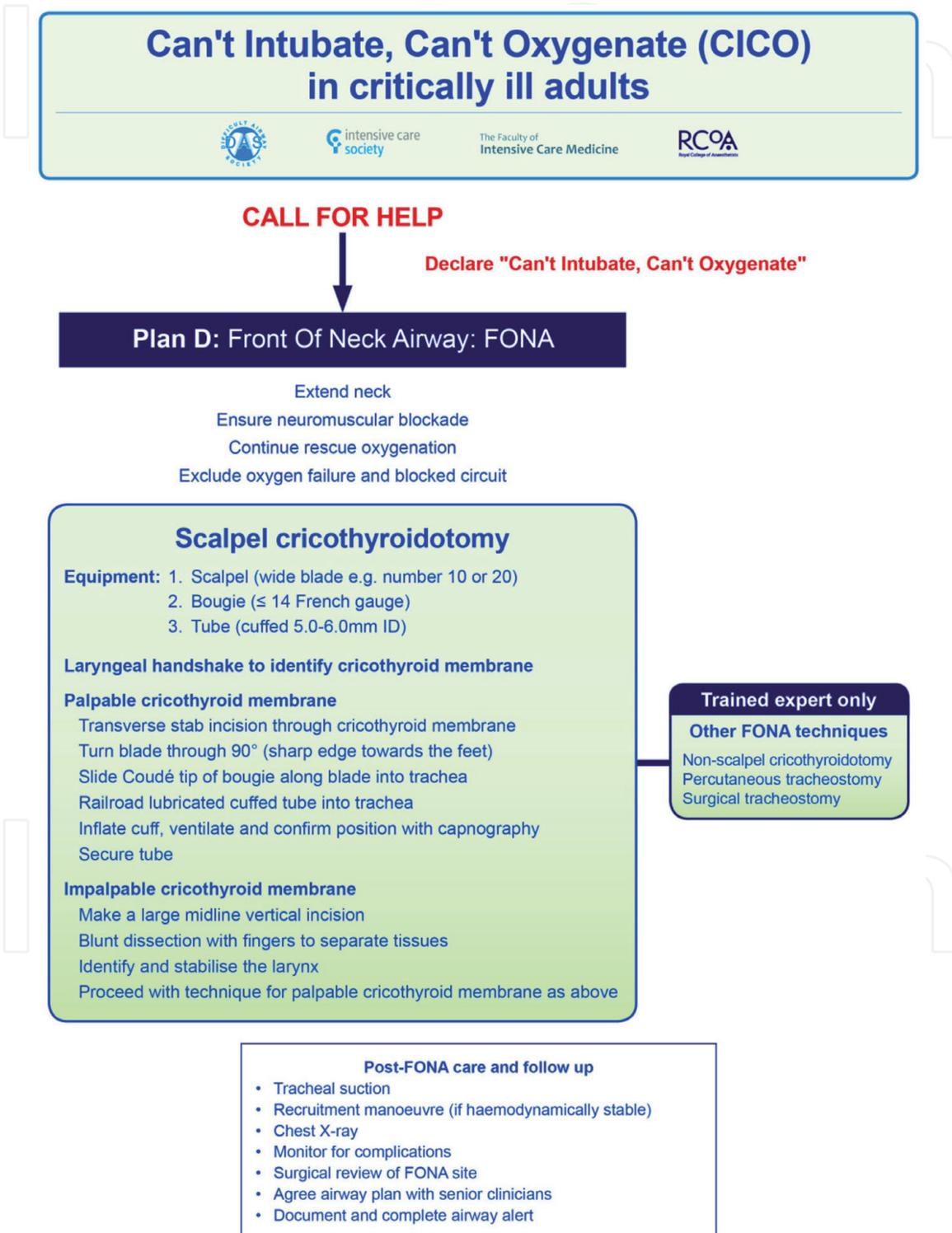
2.2.3 Plan D; life-saving front of neck airway (FONA)

Life-threatening hypoxemia development in critically ill patients is frequent [45] and might be encountered at any stage of airway intervention, hence its prevention though ETI (plan A), SGA and facemask (plan B/C) use is emphasized. Not only, plan of failure with serious hypoxemia elaboration could drive towards FONA (**Figure 8**) but also, inadequate minimal oxygenation, aspiration, difficult ventilation and failure of LMA/FOI are potential indications [46]. Forever, efforts to eliminate cannot intubate cannot oxygenate (CICO) scenario must be maintained and its causes must be corrected while preparation of FONA is being proposed. The possible reasons for CICO might be related to patient's (airway; impacted foreign body or laryngeal narrowing either from inside as laryngeal edema or from outside as high cricoid pressure), cardiovascular collapse or related to equipment failure.

Late FONA during airway management scenario is common and is responsible for its associated morbidity and mortality [43, 47]. FONA setup prior to and at declaration of CICO occurred in three steps; immediate availability of FONA set,

opening the set after one failed attempt of plan B/C and immediate FONA set use on CICO declaration [19].

FONA either scalpel cricothyroidotomy or other techniques; which need experience, specific preparations and include non-scalpel cricothyroidotomy, percutaneous tracheostomy and surgical tracheostomy. Scalpel cricothyroidotomy recommended in DAS guidelines offers the following advantages; timesaving, reliable, conducted in few steps with well-known immediately available equipment,



This flowchart forms part of the DAS, ICS, FICM, RCoA Guideline for tracheal intubation in critically ill adults and should be used in conjunction with the text.

Figure 8.
 Plan D protocol in DAS/ICS/FICM/RCoA guidelines.

high success rate, fitting for most of patients and providing definitive airway device [48]. For a brief technique steps of scalpel cricothyroidotomy and tracheostomy in ICU, will be discussed in another chapter.

Plan D (FONA) failure means a bad scenario that carries poor prognosis and must be avoided by follow-up FONA steps in a proper way as once it encountered, non-scalpel cricothyroidotomy by experienced professional, percutaneous dilatable tracheostomy and surgical tracheostomy have to be proposed immediately without delay.

2.3 Post-intervention stage

2.3.1 Post-intubation care

Not only providing airway securing device in critically ill patients is highly challenging, but post airway securing maintenance is also important to prevent airway displacement or obstruction. In addition of airway care, sedation and/or muscle relaxation are typically administered. They are not only having high-risk during intubation but also afterwards in rates of 82%; airway displacement and blockage, with 25% leading to death [49].

Furthermore; postintubation hypoxia occurred from multiple attempts, interruption of oxygenation, alveolar de-recruitment and collapse, and changes in the alveolar gas exchange may indicate an increase in initial lung volumes settings and benefiting from recruitment manoeuvres [38].

Attention payed towards recognition of red flag in intubated patients such as absent air entry on auscultation, abnormal EtCO₂, increasing peak airway pressure (PAP), unattained inhaled tidal volume and abnormal chest x-ray findings, mandate immediate management.

2.3.2 Weaning and extubation

Airway securing device in critically ill patients might be temporary for bridging a reversible and treatable medical disorder or permanent for irreversible and long-term pathology that demanding it. The former, long-term medical conditions, alternative tracheostomy have to be considered with a debate of its timing, On the other hand in reversible and corrected medical conditions; weaning and extubation must be considered in due time to avoid complications of prolonged ETT. Critically ill patients' intubation is challenging and extubation does too.

Tracheostomy might be an alternative of ETT as a definitive airway in critically ill patients in incidence of 7–19% [50] while extubation is the plan once the circumstances permit. Extubation is an elective procedure and mandates careful evaluation, preparation with the target of maintenance of oxygenation and stand-by intubation plan if extubation failure takes place.

DAS incorporated extubation guidelines in anesthesia practice and could derive that in ICU and summarized in four steps; [51].

Step 1: Plan for extubation:

- i. Considering the reasons for intubation in addition of the complications of prolonged dependence on ETT and its anatomical and physiological consequences.
- ii. "At-risk" extubation is a term used to describe the possible hazards associated with extubation process and must be considered in the plan step, especially the pre-existing factors.

- iii. A difficult airway trolley equipment and monitors should be immediately available for use.

Step 2: Prepare the extubation:

- i. Target for optimization of airway and spontaneous ventilation to ensure the success of extubation.
- ii. This could be carried out by different methods such as ETT cuff leak test; to exclude laryngeal edema, spontaneously breathing trial (SBT), gastric decompression; as gastric distension results in diaphragmatic splint and breathing restriction. The plan for airway rescue must be considered and discussed in preparation.

Step 3: Perform extubation:

- i. Avoid interruption of oxygenation by pre-extubation oxygenation via FIO₂ of 100% O₂.
- ii. Patient's position; without adequate supporting evidence any one over the other, it's advisable extubation in head-up or semi-recumbent position especially in obese patients.
- iii. Gentle suctioning of oropharyngeal cavity and extubation in fully awake state or conscious-sedation state using Remifentanyl [52] might be alternatives.

Step 4: post-extubation care:

- i. Beware of Warning signs of early airway compromise; stridor, obtunded breathing and agitation.
- ii. Standard monitoring should be continued in post-extubation phase.
- iii. Standard respiratory care for patients with airway compromise.
- iv. Upright position, and high-flow humidified oxygen administration.
- v. Documentation and recommendations for future management.
- vi. Clinical details and instructions for extubation and post-extubation care should be recorded focusing on difficulties and details of airway management and future recommendations should be recorded.

2.4 Special circumstances

1. Airway management for ICU procedures like bronchoscopy, please refer to other chapters.
2. Full stomach in ICU, will be discussed in another chapter.
3. Previous tracheostomy that recently disconnected, it's advisable to re-cannulate the stoma but proceed for FONA should not be delayed [19].

4. ETT exchange in ICU remains common for many reasons that happening frequently such as ETT displacement or occlusion by crusted mucus, cuff rupture or surgical procedures mandate other ETT type. This task has to be taken seriously and reviewing the initial ETI documentation is essential and will provide a logical ETT exchange plan. Tube-exchange catheter is designed for that, providing its use with DL or VL which has superior glottic view, greater success rate and fewer complications [53]. New ETI could be another alternative but with the previous ETI documentation, all precautions and recommendations discussed earlier must be considered.
5. Varieties of abnormal clinical status might be accompanying the airway management in critically ill patients such as obesity, burn, pregnancy etc.... and required specific considerations, please review the book chapters for more details.
6. Specific alteration in airway management in COVID19 might be considered despite few data available. High Flow Nasal Cannula (HFNC) suggested to reduce the requiring supported ventilation [54] and NIV might reduce the rate of tracheal intubation [55]. Tracheal intubation in COVID 19 patients is considered as highest risk for health care professionals cross-infection and could be carried out in controlled environment [56]. More details about this topic will be available in specific chapter.

3. Training and skills maintenance

Critically ill patients usually are underestimated as specific airway difficulty and being at high risk of failure. Not only due to infrequent training of focused airway and crisis management but also, physicians may neither have anesthesia rotation nor airway skills required for difficult airway management. Training on sole skills performance is unsatisfactory to achieve maximum safety [57] and ineffective teamwork that includes poor communication, lack of shared targets, situational awareness, role assignment, leadership, coordination, mutual respect and post-event debriefings is associated with poor patients' outcome [58].

Focused risk assessment training, prevention of hypoxia, airway red flags, early call for help and request for advanced airway skills in concomitant with specific protocols and guideline presented. Team training, focused airway management training courses and workshops including simulation-based education are crucial and step up for airway management in both ED and ICU suites.

The crisis resource management (CRM) techniques from aviation industry has been advocated for use in ICU to promote a team approach to patient care and safety in critical settings [59]. The committee on quality of healthcare in America believes that health care organization should accomplished team training programs for health care professionals in critical care areas using demonstrating message such as crew resources management techniques employed in aviation, including simulation as people make fewer errors when they work in teams [60].

4. Conclusion

Airway management in critically ill patient continues to be challenging for health care professionals even for expertise requiring implementation of specific guidelines and protocols to eliminate the its adverse consequences. Airway management tools

and skills needed, could be attained through formal training by anesthesia clinical rotation, airway management courses, workshops and simulation training.

Teamwork is a key for success and must be preceded by debriefing and specific task assignments. Plan of failure in a step wise approach for success and airway management should be considered early without delay that will be associated with more difficulties and unwanted outcome.

Optimization of oxygen delivery throughout the airway intervention is mandatory and should not be compromised for any reason. FONA should be considered in primary preparation and must be done in appropriate time without delay. Documentations and records must involve all stages of airway management and include details of difficulties.

Author details

ELSayed Elkarta^{1*} and Magdy Eldegwy²

1 Al-Azhar University, Faculty of Medicine in Damietta, New Damietta, Egypt

2 Al-Azhar University, Faculty of Medicine in Cairo, Cairo, Egypt

*Address all correspondence to: salkarta@hotmail.com

IntechOpen

© 2020 The Author(s). Licensee IntechOpen. This chapter is distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/3.0>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited. 

References

- [1] Watts ER, Walmsley SR. Inflammation and Hypoxia: HIF and PHD Isoform Selectivity. *Trends Mol Med*. 2019 Jan; 25(1):33-46
- [2] West, J.B.: *Respiratory Physiology: 2011, The Essentials*, 9th edn. Philadelphia: Lippincott, Williams and Wilkins.
- [3] O'Driscoll, B.R., Howard, L.S., Davidson, A.G: *Guidelines for emergency oxygen use in adult patients*. *Thorax*; 2008,63(Suppl VI): vi1-73.
- [4] Nolan, J., Soar, J., Lockey, A. et al.: *Advanced Life Support*, 2011, 6th edn. London: Resuscitation Council.
- [5] Griesdale DE, Bosma TL, Kurth T, Isac G, Chittock DR. Complications of endotracheal intubation in the critically ill. *Intensive Care Med* 2008; 34: 1835-42
- [6] Jaber S, Amraoui J, Lefrant JY, et al. Clinical practice and risk factors for immediate complications of endotracheal intubation in the intensive care unit: a prospective, multiple-center study. *Crit Care Med* 2006; 34: 2355-61
- [7] Bowles TM, Freshwater Turner DA, Janssen DJ, Peden CJ, on behalf of the RTIC Severn Group. Out-of-theatre tracheal intubation: prospective multicentre study of clinical practice and adverse events. *Br J Anaesth* 2011; 107: 687-92
- [8] Nolan JP, Kelly FE. Airway challenges in critical care. *Anaesthesia* 2011; 66: 81e92
- [9] Cook TM, Woodall N, Harper J, Benger J. *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* 2011; 106: 632-42
- [10] A K Nørskov 1, C V Rosenstock, J Wetterslev, G Astrup, A Afshari, L H Lundstrøm. Diagnostic Accuracy of Anesthesiologists' Prediction of Difficult Airway Management in Daily Clinical Practice: A Cohort Study of 188064 Patients Registered in the Danish Anaesthesia Database. *Anaesthesia* 2015; 70(3):272-81
- [11] De Jong A, Molinari N, Terzi N, et al. Early identification of patients at risk for difficult intubation in the intensive care unit: development and validation of the MACOCHA score in a multicenter cohort study. *Am J Respr Crit Care Med* 2013; 187: 832e9
- [12] Yildiz TS, Korkmaz F, Solak M, Toker K, Erciyes N, Bayrak F, Ganidagli S, Tekin M, Kizilkaya M, Karsli B, et al. Prediction of difficult tracheal intubation in Turkish patients: a multicenter methodological study. *Eur J Anaesthesiol* 2007; 24:1034-1040.
- [13] Shallik N, Labib A, Ganaw A, Shaikh N, Moustafa A, Hammad Y. Virtual bronchoscopy and 3D reconstruction in the critical care setting. *Qatar Medical Journal*. 2020 Feb 6;2019(2-Qatar Critical Care Conference Proceedings):81
- [14] Frerk C, Mitchell VS, McNarry AF, et al. Difficult Airway Society 2015 guidelines for management of unanticipated difficult intubation in adults. *Br J Anaesth* 2015; 115: 827e48
- [15] Kristensen MS, Teoh WH, Rudolph SS. Ultrasonographic identification of the cricothyroid membrane: best evidence, techniques, and clinical impact. *Br J Anaesth* 2016; 117: i39e48
- [16] Tanoubi I, Drolet P, Donati F. Optimizing preoxygenation in adults. *Can J Anaesth* 2009; 56: 449e66

- [17] Mort TC. Preoxygenation in critically ill patients requiring emergency tracheal intubation. *Crit Care Med* 2005; 33: 2672e5
- [18] Pandey M, Ursekar R, Aphale S. 3 minutes tidal breathing a gold standard technique of pre-oxygenation for elective surgeries. *Innov J Med Health Sci* 2014; 4: 194e7
- [19] Higgs A, McGrath B.A, Goddard C, Rangasami J, Suntharalingam G, Gale R, Cook T.M and on behalf of Difficult Airway Society, Intensive Care Society, Faculty of Intensive Care Medicine, Royal College of Anaesthetists. Guidelines for the management of tracheal intubation in critically ill adults. *BJA*, 2018; 120 (2): 323e352
- [20] Delay JM, Sebbane M, Jung B, et al. The effectiveness of noninvasive positive pressure ventilation to enhance preoxygenation in morbidly obese patients: a randomized controlled study. *Anesth Analg* 2008; 107: 1707e13
- [21] Jaber S, Monnin M, Girard M, et al. 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 center, blinded, randomized controlled OPTINIV trial. *Intensive Care Med* 2016; 42: 1877e87
- [22] Brindley PG, Simmonds MR, Needham CJ, Simmonds KA. Teaching airway management to novices: a simulator manikin study comparing the 'sniffing position' and 'win with the chin' analogies. *Br J Anaesth* 2010; 104: 496e500
- [23] Weingart SD, Levitan RM. Preoxygenation and prevention of desaturation during emergency airway management. *Ann Emerg Med* 2012; 59: 165e75
- [24] Dixon BJ, Dixon JB, Carden JR, et al. Preoxygenation is more effective in the 25 degrees head-up position than in the supine position in severely obese patients: a randomized controlled study. *Anesthesiology* 2005; 102: 1110e5
- [25] Association of Anaesthetists of Great Britain and Ireland. Recommendations for standards of monitoring during anaesthesia and recovery 2015. *Anaesthesia* 2016; 71: 85e93
- [26] Koerber JP, Roberts GE, Whitaker R, Thorpe CM. Variation in rapid sequence induction techniques: current practice in Wales. *Anaesthesia*. 2009; 64:54-59.
- [27] Schlesinger S, Blanchfield D. Modified rapid-sequence induction of anesthesia: a survey of current clinical practice. *Aana J*. 2001; 69:291-298.
- [28] Scott D. Weingart, Seth Trueger, Nelson Wong, Joseph Scofi, Neil Singh, Soren S., Rudolph: Delayed Sequence Intubation; A Prospective Observational Study. *Ann Emerg Med*. 2014;1-8.
- [29] Upchurch CP, Grijalva CG, Russ S, et al. Comparison of etomidate and ketamine for induction during rapid sequence intubation of adult trauma patients. *Ann Emerg Med* 2017; 69: 2433.e2.
- [30] Kaushal RP, Vatal A, Pathak R. Effect of etomidate and propofol induction on hemodynamic and endocrine response in patients undergoing coronary artery bypass grafting/mitral valve and aortic valve replacement surgery on cardiopulmonary bypass. *Ann Card Anaesth* 2015; 18:172178.
- [31] Jabre P, Combes X, Lapostolle F, Dhaouadi M, Ricardhibon A, Vivien B, et al. Etomidate versus ketamine for rapid sequence intubation in acutely ill patients: a multicenter randomized controlled trial. *Lancet*. 2008; 374:293-300.

- [32] Seisa MO, Gondhi V, Demirci O, et al. Survey on the current state of endotracheal intubation among the critically ill. *Journal of Intensive Care Medicine* 2016; 40:17.
- [33] Rocchio MA, Sylvester K, Beik N, et al. Retrospective review of propofol versus etomidate during rapid sequence intubation in the emergency department at a tertiary academic center. *Pharmacol Pharm* 2017; 8: 23141.
- [34] Bruder EA, Ball IM, Ridi S, Pickett W, Hohl C. Single induction dose of etomidate versus other induction agents for endotracheal intubation in critically ill patients. *Cochrane Database Syst Rev.* 2015;1:CD010225.
- [35] Heuer JF, Barwing TA, Barwing J, et al. Incidence of difficult intubation in intensive care patients: analysis of contributing factors. *Anaesth Intensive Care* 2012; 40: 120e7
- [36] Marsch SC, Steiner L, Bucher E, et al. Succinylcholine versus rocuronium for rapid sequence intubation in intensive care: a prospective, randomized controlled trial. *Crit Care* 2011; 15: R199
- [37] Reynolds SF, Heffner J. Airway management of the critically ill patient. *Chest.* 2005; 127:1397-412.
- [38] Frova G, Tuzzo D. Anesthesia accidents: accidental esophageal intubation. *Minerva Anestesiol* 1999; 65: 362e6
- [39] Kelly FE, Cook TM. Randomized controlled trials of video-laryngoscopy vs. direct laryngoscopy on intensive care are needed. *Intensive Care Med* 2014; 40. 765e5
- [40] Amathieu R, Combes X, Abdi W, et al. An algorithm for difficult airway management, modified for modern optical devices (Airtraq laryngoscope; LMA CTrach TM): a 2- year prospective validation in patients for elective abdominal, gynecologic, and thyroid surgery. *Anesthesiology* 2011; 114: 25e33
- [41] Grier G, Bredmose P, Davies G, Lockey D. Introduction and use of the ProSeal laryngeal mask airway as a rescue device in a pre-hospital trauma anaesthesia algorithm. *Resuscitation* 2009; 80: 138e41
- [42] Halwagi AE, Massicotte N, Lallo A, et al. Tracheal intubation through the I-gel TM supraglottic airway versus the LMA Fastrach™: a randomized controlled trial. *Anesth Analg* 2012; 114: 152e6
- [43] Cook TM, Woodall N, Frerk C, on behalf of the Fourth National Audit Project. 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 1: anaesthesia. *Br J Anaesth* 2011; 106: 617e31
- [44] Mehmet Sahin 1, Daniel Anglade, Martine Buchberger, Adrien Jankowski, Pierre Albaladejo, Gilbert R Ferretti. Case Reports: Iatrogenic Bronchial Rupture Following the Use of Endotracheal Tube Introducers. *Can J Anaesth.* 2012 Oct;59(10):963-7.
- [45] Grimaldi, D., Hraiech, S., Boutin, E. et al. Hypoxemia in the ICU: prevalence, treatment, and outcome. *Ann. Intensive Care* 2018; 8, 82.
- [46] Carron M, Freo U, Michielan F, Ori C. Effects of tracheal intubation on ventilation with LMA classic for percutaneous dilation tracheostomy. *Minerva Anestesiol* 2010; 76: 181e7
- [47] ANZCA Airway Management Working Group. Transition from supraglottic to infra-glottic rescue in the 'can't intubate can't oxygenate' (CICO) scenario. 2014. Available from: <http://www.anzca.edu.au/documents/>

report-from-the-anzca-airway-management-working-gr.pdf. [Accessed 17 February 2017]

[48] Hubble MW, Wilfong DA, Brown LH, Hertelendy A, Benner RW. A meta-analysis of prehospital airway control techniques part II: alternative airway devices and cricothyrotomy success rates. *Prehosp Emerg Care* 2010; 14: 515e30.

[49] Mort TC, Braffett BH. Conventional versus video laryngoscopy for tracheal tube exchange: glottic visualization, success rates, complications, and rescue alternatives in the high-risk difficult airway patient. *Anesth Analg* 2015; 121: 440e8

[50] Shah RK, Lander L, Berry JG, Nussenbaum B, Merati A, Roberson DW. Tracheotomy outcomes and complications: a national perspective. *Laryngoscope* 2012; 122: 25e9

[51] Popat M, Mitchell V, Dravid R et al. Difficult Airway Society Guidelines for the management of tracheal extubation. *Anaesthesia*. 2012;67(3):318-340.

[52] Nishina K, Mikawa K, Maekawa N, Obara H. Fentanyl attenuates cardiovascular responses to tracheal extubation. *Acta Anaesthesiologica Scandinavica* 1995;39: 85-9.

[53] Thomas AN, McGrath BA. Patient safety incidents associated with airway devices in critical care: a review of reports to the UK National Patient Safety Agency. *Anaesthesia* 2009; 64: 358e65

[54] Rochwerg B, Solo K, Darzi A, et al. Update Alert: Ventilation Techniques and Risk for Transmission of Coronavirus Disease, Including COVID-19. *Ann Intern Med* 2020.

[55] Schünemann HJ, Khabsa J, Solo K, et al. Ventilation Techniques and Risk for Transmission of Coronavirus

Disease, Including COVID-19: A Living Systematic Review of Multiple Streams of Evidence. *Ann Intern Med* 2020; 173:204.

[56] El-Boghdadly K, Wong DJN, Owen R, et al. Risks to healthcare workers following tracheal intubation of patients with COVID-19: a prospective international multicentre cohort study. *Anaesthesia* 2020.

[57] Gaba DM. Structural and organizational issues inpatient safety: a comparison of health care to other high-hazard industries. *Calif Manag Rev*. 2000; 43:83-102

[58] McGaghie WC, Issenberg SB, Petrusa ER, Scalese RJ. A critical review of simulation-based medical education research: 2003-2009. *Med Educ*. 2010; 44:50-63

[59] Gaba DM, Fish KJ, Howard SK. Crisis management in anesthesia. New York: Churchill Livingstone; 1994

[60] Kohn LT, Corrigan JM, Donaldson MS, editors. To err is human: building a safer health system. Washington (DC); 2000