Videolaryngoscopy in the Intensive Care Unit: We could Improve ICU Patients Safety

Eugenio Martínez Hurtado,
Miriam Sánchez Merchante, Sonia Martín Ventura,
María Luisa Mariscal Flores and
Javier Ripollés Melchor

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Abstract

Tracheal intubation is one of the most common and dangerous procedures in the intensive care units (ICU), and is usually done in more difficult conditions than in the operating room. Intubation failure can occur unexpectedly, and is the second most common event reflected in the ICU in the NAP4. Complications associated with airways were more likely to occur in ICU than in the operating room (severe hypoxemia, arrhythmia, hypotension, cardiovascular collapse, etc.), and generates more frequent damage to the patient. The theoretical benefits of videolaryngoscopes, as proper and correct use, offer the potential to reduce the difficulty of intubation in the ICU. In recent years, the role of videolaryngoscopes in ICU has been the subject of debate. Numerous studies have shown increased morbidity when performing multiple attempts at tracheal intubation. Videolaryngoscopes allow a view of the entrance of glottis independent of the line of sight, and have also been shown to improve glottis and intubation success rates in emergency and emergency services, in the prehospital setting, and specifically in patients with known predictors of difficult airway (DA).

Keywords: tracheal intubation, NAP4, complications, videolaryngoscopes, difficult airway, airway management, laryngoscopy, critical patient

1. Introduction

Airway management (AM) in intensive care units (ICU) is a common practice that is usually performed in more complicated conditions than in the operating room, where it is performed on a scheduled basis. The fundamental difference is that these patients are frequently in a situation of

Figure 1. Airtraq videolaryngoscope.

hypoxemia and cardiovascular collapse, so in many situations, the airway management in these clinical conditions is often complicated, if not emergency. Therefore, it is usually considered that these patients present, at the beginning, a possible difficult airway (DA).

Although failure to manage AM sometimes occurs unexpectedly, it is known to be the second most common event reflected in NAP4 in the ICU [1]. So, all patients admitted in the ICU should be considered at risk.

The airway approach in this environment has gained interest in recent years, especially after NAP4, in which airway complications were found to be more likely to occur in the ICU than in the operating room (severe hypoxemia, in addition to arrhythmias, hypotension, and cardiovascular collapse), and more frequently caused harm to the patient. This study specifically mentioned the theoretical benefit of videolaryngoscopes (VL), since their proper and correct use would offer the potential to reduce the difficulty of intubation in the ICU (**Figure 1**).

Other important conclusions drawn from the NAP4 were the scarce airway assessment performed in the critical units and did not allow us to anticipate a DA, resulting in poor planning. It was also observed that, in the context of an unexpected DA, the limited ability to modify the established plan may lead to a failure to resolve the situation.

The utility of videolaryngoscopy in anesthesia is widely recognized and endorsements advocating its use have been incorporated in the UK and American Difficult Airway Society guidelines [2, 3].

2. Epidemiology

The degree of difficulty with face mask ventilation (FMV) and intubation with direct laryngoscopy (DL) is very variable according to the studies and although the degree of difficulty for intubation does not have to correspond to the difficulty for ventilation with facial masks, if they occur together in the same patient, the consequences can be catastrophic [4].

Traditionally, the difficulty for laryngoscopy vision is difficult to intubate [5, 6].

In general, the incidence of Cormack-Lehane grades 3/4 and 4/4 ranges from 1 to 10%, and 2–8%, respectively. These figures are up to 7.9% in pregnant women requiring general anesthesia, with 2% of cases being "*very difficult intubation*", an incidence similar to difficult orotracheal intubation (OTI) in urgent non-obstetric surgical patients.

Finally, the catastrophic situation of "*can't-intubate-can't-oxygenate*" (CICO) can occur with an incidence of 1–3 per 10,000 patients to 1 per 50,000 patients according to the authors.

All these figures vary between studies, mainly because there is no unanimity in the definitions or terms related to AM.

Within the specific context of an ICU, the incidence of DA rises to 10–20% [7–12].

Facial mask ventilation (FMV) is a fundamental element of the AM that would ensure patient oxygenation between the different intubation attempts. It has been classically described an incidence of difficulty FMV of 0.08% [5].

In 2004, a scale of 4 degrees of difficulty FMV was established, assigning a score of 0–4 according to the difficulty found [13], which was later used in a study of 22,660 patients [14], Finding a degree of difficulty of:

- Grade 1: easy FMV (77.4%).
- Grade 2: easy FMV with an oral cannula or other adjuvants (21.1%).
- Grade 3: difficult FMV (inadequate, unstable or requiring two operators) (1.4%).

- Grade 4: inability FMV (0.16%).
- Grade 3 or 4 + difficult intubation: 0.37%.

In order to increase statistical power in some variables of the previous study, in 2009, a new study was carried out, collecting more than 50,000 patients [15]. It was recognized that the incidence of impossible FMV, defined as "*the inability to ventilate with facial masks despite the use of facilitating devices and 2-hand ventilation*", was found to be around 0.15%.

3. Particularities of airway management in the critical patient

Critical patient intubation is often performed in ICU, but can also be performed in locations away from the operating room, where working conditions and available materials are often inadequate. The difficulty rate of orotracheal intubation in emergency situations is 3 times higher than the programmed procedure, with a reported incidence of 10–20% failure at the first-attempt [7], with a complication rate 50 times higher than those found during anesthesia [1].

The AM of the critically ill patient may be complicated by the anatomical characteristics involving the visualization of glottis opening, or the difficult passage of the tracheal tube through the vocal cords, or by the clinical situation itself, which may contribute to the cardiovascular collapse. Among these causes of physiologic DA are hypoxemia, hypotension, severe metabolic acidosis, and right ventricular failure [16]. In fact, approximately 20% of patients in the ICU will experience critical hypoxemia, which, in the worst case, leads to death. Other common complications are esophageal intubation, aspiration, and selective bronchial intubation, among others.

DA is defined as "*that clinical situation in which an experienced anesthesiologist present difficulties with ventilation with a face mask, difficulty with OTI, or both*". Likewise, difficult intubation can be defined as "*the need for 3 or more attempts for OTI, or more than 10 minutes to achieve it*" [2].

However, despite handling the DA forced to take decisions and perform actions quickly and effectively, the truth is that there is no unanimity in the definitions or terms related to AM, because "the DA not exists, in reality, but is a complex interaction between the patient, the anesthetist, the available equipment and other circumstances" [17].

Until a few years ago, the available systems of evaluation have had in little consideration factors not related to the patient. Some factors that complicate and diminish the safety of the management of the AM such as:

- Experience.
- Pressure of time-urgency.
- Availability of suitable equipment.
- Location.
- Human factors.

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However, it is currently considered "*management of context-sensitive airway*", where a gaseous exchange is more valued than the tracheal intubation itself [18], which consists of four ventilation and oxygenation methods:

1. Facial mask.
2. Supraglottic or extraglottic devices.
3. Endotracheal tube.
4. Surgical AM.

The use of any of these methods depends not only on the devices but also on the situation facing the professional. In this management of context-sensitive MA, maintenance of the patient's gauche exchange is the priority and should not be "*device dependent*". Thus, careful evaluation of the "*context*" interpretation is essential for the safe practice of MA management.

The concept "*context-sensitive AM*" acquires special relevance in critically ill patients, and there are several causes that make it difficult to manage their AM:

1. Non-patient dependent:
   - Who manages airway?
   - Where is the patient?
   - What equipment and medication are available?
   - Who helps?
2. Dependent patient:
   - Predictive tests of AD.
   - Pathology of the patient (hemorrhage, edema, trauma, increased secretions, etc.).

4. Complications of intubation in the critical patient

The primary indication for OTI in ICU is the acute respiratory failure. Weakness and fatigue of respiratory muscles (ventilatory failure) and disruption of gas exchange (respiratory failure) are common, and the risk of hypoxemia and cardiovascular shock during the OTI process is high, ranging from 15 to 50%.

Critical patient intubation presents life-threatening complications in more than one-third of cases [19]. The most common are respiratory and hemodynamic alterations [20]. The main adverse event associated with the technique is hypoxemia with a dramatic decrease in peripheral oxygen saturation (SapO2) despite adequate preoxygenation. In almost half of the cases, the indication for tracheal intubation is due to an acute respiratory failure with a previous SapO2 of less than 90% that supports the appearance of severe hypoxemia.

The second complication due to its frequency is hemodynamic alteration with hypotension after intubation, associated or not with desaturation. Mort reported 60 cardiac arrests during 3035 intubations outside the operating room (incidence of 2%) [21]. About 83% of these patients experienced severe hypoxemia (SatpO2 < 70%). The choice of the drug suitable for anesthetic induction is very important to minimize hypotension in the critical.

Other complications described in the literature are esophageal intubation and pulmonary aspiration. The former increases the risk of cardiac arrest by 15 times.

NAP4 reported that ICU, far from representing a safe place to operate the airway, were a place of potential danger. Airway-related complications were more likely to occur in the ICU than in the operating room, and more often resulted in harm to the patient. Thus, the rate of airway complications that appeared in the ICU was more than 50 times higher than those found during anesthesia, and 61% of the ICU patients reported on NAP4 suffered neurological damage or death, compared to 14% during the anesthetic procedure and 33% in the emergency department. Although most of the potentially fatal airway events in the ICU were due to especially tracheal tube displacement or tracheostomy (especially in obese patients), difficulties were also identified associated with esophageal intubation, rapid sequence intubation, and failure techniques of the rescue of the airways [1].

There are four factors that are independently associated with a serious complication during the procedure:

1. Age is a factor that cannot be modified and is accompanied by a worse response of the organism to any aggression.

2. Second, there are two factors depending on the patient's previous physiological status, the presence of hypotension, and/or hypoxemia conditions an increased risk of complications. In some cases, these factors can be modified by optimizing blood pressure and oxygenation.

3. The presence of secretions in the oropharyngeal cavity hinders laryngoscopic vision and has been associated with an increase in the rate of failure of tracheal intubation.

4. Lastly, the need for more than one attempt for intubation increases the risk of complications. A number greater than two attempts increases the risk of hypoxemia, bradycardia, aspiration of gastric contents, and cardiac arrest exponentially [21].

The presence of two clinicians reduces the risk of complications.

5. Approach of the airway management in the critical patient

The aims of the AM, understood as the accomplishment of maneuvers and the use of devices that allow adequate and safe ventilation to patients who need it, is to guarantee the oxygenation in a situation of potential vital risk for that patient.

The optimal AM and ventilation of critical patients remain a basic pillar in survival, evolution, and prognosis, with OTI being the gold standard in these situations.

Most patients requiring tracheal intubation and mechanical ventilation in the ICU are, in contrast to those requiring these procedures in an operating room, patients with a circulatory and/or respiratory compromise. Therefore, the intubation procedure should be non-aggressive and atraumatic.

The cardiorespiratory instability usually presented by the seriously ill patient (with reduced functional residual capacity and safe apnea time), together with the urgent nature of the situation, the low predictability of the possible scenarios, jointly with the fact that it is often not possible ensure adequate gastric emptying, determine that the intubation of critical airway is a high-risk procedure. For this reason, all critical patients should be initially managed as potential AD.

The results of the NAP4 audit are parallel to other studies that consider that multiple attempts at intubation in the critical patient result in a high incidence of adverse events [22]. In order to limit the number of attempts to two and to ensure success, interventions such as an adequate patient position and the existence, at the bedside, of correct material equipment and experienced personnel are necessary.

The assessment of the airway in the critical patient may be complex, but adequate planning should be part of the daily approach to the airway. This assessment must include the factors that predict a DA that we routinely use in the anesthesia consultation. The patient's position, the additional help present, and the available material must be evaluated prior to anesthetic induction. In addition, the physiological characteristics of the subject such as the full stomach and situations that favor desaturation (obesity and pulmonary shunt) should be considered.

The oxygenation of patients before and during intubation is of paramount importance [23]. Premaneuver denitrogenate has been shown to be useful as oxygenation with nasal goggles during apnea. The administration of high concentrations of oxygen through high-flow nasal glasses (HFNG) seems to offer advantages over the classic preoxygenation models. It provides some degree of positive pressure even during laryngoscopy without requiring patient collaboration [24].

Historically, direct laryngoscopy has been the most commonly used method for intubation in critically ill patients. Alternatives such as luminous stylet, supraglottic device, and flexible fibrobronchoscope are hardly used outside the surgical area. VLs have been proposed as an initial approach by some authors, but their implementation is being limited and reserved as a rescue technique. It is true that these devices improve the vision of the glottis, but in less-experienced hands, they slow the procedure and, in critical patients with few reserves, additional few seconds can have fatal consequences.

6. Videolaryngoscopes in the ICU

In conventional airway management, routine OTI with traditional direct laryngoscopy (DL) is still the common practice [25, 26], with the Macintosh as standard gold DL, a device created just 10 years before the first ICU was Inaugurated by the anesthesiologist Bjorn Ibsen in Copenhagen (December 1953) [27, 28]. On the other hand, in DA cases, the technique of choice for intubation is the use of the fiber optic bronchoscopy (FOB), although there are more and more studies in which videolaryngoscopy is used as an alternative approach in induced/sleep or awake patient, since FOB is an expensive, fragile, and requires regular maintenance, is complex to dispose of in emergency situations or in prehospital emergencies, and requires previous training.

Failure of endotracheal intubation using Classical Direct Laryngoscopy with a Macintosh laryngoscope or other technique may occur unexpectedly. And, since the second most common event reflected in the NAP4 reports on the ICU was failed intubation, proper and correct use of videolaryngoscopes (VL) would offer the potential to reduce the difficulty of intubation in general in the ICU [1, 29].

Numerous studies have shown increased morbidity when performing multiple attempts at tracheal intubation. Videolaryngoscopes allow a view of the entrance of glottis independent of the line of sight (LI), especially those that have angled blades. The fact that the image sensor is in the distal part of the blade causes us to have a panoramic view of the glottis, without the need to "*align the axes*", thus avoiding hyperextension of the head, and in practice having a Laryngoscopy Cormack-Lehane (CL) grade 1 or 2 (CL 1/4 or 2/4) in 99% of the cases (**Figure 2**).

VL have also been shown to improve glottis and intubation success rates in emergency and emergency services, in the prehospital setting, and specifically in patients with known predictors of DA [30].

However, achieving CL grade 1 laryngoscopy (CL 1/4) in laryngoscopy with a VL does not guarantee the success of OTI, which is relatively frequent in VLs that have a curved leaf, especially during the learning stage [31, 32].

Previous studies with novice and experienced anesthetists have suggested that the learning curve with an optical device can be around 20 applications to be competent to manage [33].

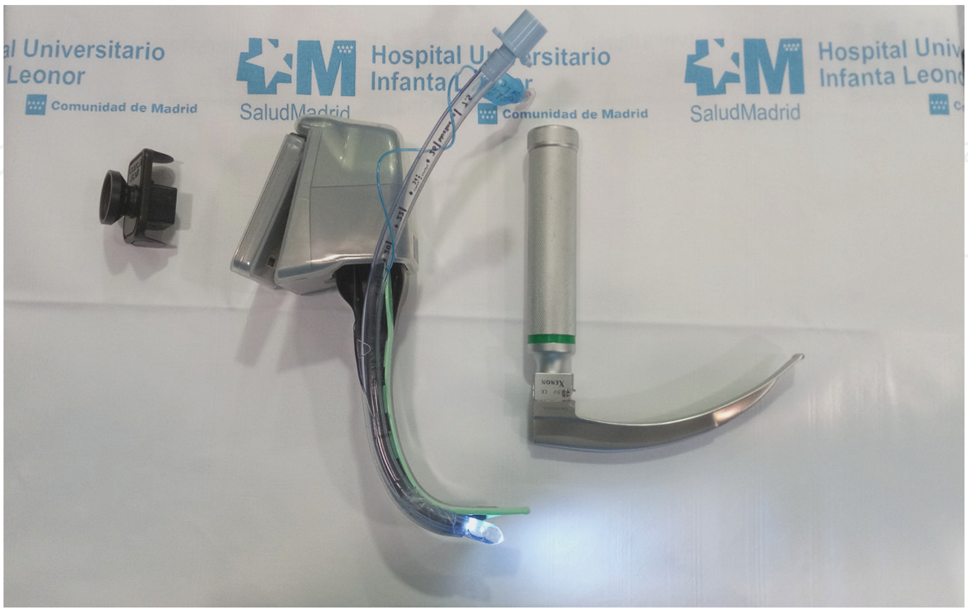

Figure 2. Glottic view differences.

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Although these numbers are lower than those suggested by Greaves (80% of competence acquired with 30 cases, and complete with 100 cases), the video imaging technology of these new devices offers a shared vision between instructor and student [34], which can facilitate the teaching of airway anatomy, critical assessment of technique, and feedback. This may lead to skill acquisition faster than that achieved with traditional training with direct laryngoscopy [35].

This difficulty in achieving intubation despite the correct exposure of the larynx even in expert hands may be finally impossible, and success depends more on the operator's ability and patient's airway characteristics than on the own device [36]. However, in an attempt to overcome this problem, channeled videolaryngoscopes have the advantage of orienting the endotracheal tube (ETT) toward the trachea, allowing directed intubation with a little manipulation of the airway.

On the other hand, the evidence suggests that the use of indirect laryngoscopy (IL) improves the overall success rate of emergency/emergency tracheal intubation, as well as reduces the incidence of esophageal intubation when compared to conventional direct laryngoscopy (LD) [36].

In addition to this, we must mention that the VL, thanks to its good image quality, allow to easily recognize the structures of the larynx to achieve an image with a field between 45° and 60°, as opposed to the distant and tubular vision of the classical laryngoscopy (about 15°).

This image also allows to be certain about both the success of the intubation and the depth of insertion of the ETT, and can also easily recognize and correct esophageal intubation, a serious cause of morbidity and mortality. And another added advantage is that they provide an LED light, of greater luminous intensity than the conventional one and with a spectral irradiation closer to the human eye.

The NAP4 (the 4th National Audit Project on Major Complications in Airway Management in the UK) specifically mentions the theoretical benefit of videolaryngoscopes [1], with evidence that they can be more efficient than a Macintosh laryngoscope conventional.

For these and other reasons, these optical devices were incorporated into the airway management guidelines by the ASA as valid options in both the DA as usual, including, without excluding or limiting, laryngoscopes with different sizes and types of blades, VL, facial masks or supraglottic airway devices (SAD) such as laryngeal mask (LMA) or Fastrach® (ILMA), laryngeal tube, etc., fibrobronchoscope (FBO), extraglottic device (Frova, Eischman, etc.), nasal intubation, etc. [2].

6.1. Features

The characteristics that would define an ideal intubation device are described in **Table 1**.

During the last few years, many types of rigid, semi-rigid, optical, fiber optic and video-assisted laryngoscopes have been developed, as well as stiff and flexible stylets, as well as the classic flexible fibrobronchoscope, all of them with a common goal: to solve a classic problem for anesthesiologists, the difficult airway. The clinical evidences tell us about the real usefulness of all these devices in the solution of the problem for which they were designed. Scientific evidence of its use, the advantage of one over another, and the choice of each of them in a particular patient are yet to be determined.

• Light and portable.
• Economic and one-time use. Disposable, no risk of cross contamination.
• Short learning curve. Easy intubation with minimal skills.
• Good glottal visibility.
• Presence of an anti-fogging system that ensures the visualization of the airway despite the presence of secretions.
• Rapid orotracheal intubation, with minimal manipulation of the patient.
• Suitable for all types of ETT.
• Allow the administration of O_2/ventilate.
• Allow aspiration.
• It does not produce hemodynamic changes.
• Adaptable to the anatomy.
• Can be used with little mouth opening.
• Do not need cervical hyperextension.
• It can be used with the patient in any position.
• Possibility of connection to monitor for teaching.
• It can be used in awake patients.
• Multiple display options.
• Storage capacity and image integration.

Table 1. Characteristics of an ideal intubation device.

At the moment, all the VL present as common characteristics [37–44]:

1. *Technically*: they present a wider image, high resolution, with improvement of the degree of laryngoscopy. Indirect vision of the glottis can be obtained in different ways:
   (a) Camcorder whose digital image is transmitted to a screen of an external monitor.
   (b) Beam of optical fibers.
   (c) System of prisms, which transmit the image through a system of lenses.
2. *Procedure*: similar to the Macintosh or Miller laryngoscope, although on other occasions it is inserted through the midline, or fiber optic bronchoscope (FOB).
3. *Teaching*: allow to teach and show multiple visions, the assistant visualizes and can see the result of laryngeal manipulation. The procedure can be saved and remembered. It facilitates the learning of alternative techniques to FBO, etc.
4. *Research*: images can be stored.
5. *Comfort for the user*: more comfortable posture, less contact with secretions, blood, etc.

6.2. Classification

Resulting the classifications proposed by Pott et al. [43], Healy et al. [38], and Niforopoulou et al. [44], although all VLs allow a view of the entrance of glottis independent of the line of sight (indirect laryngoscopy [LI]), could be classified according to the type of blade [42]:

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1. VL with "*Standard*" rigid blade, similar to the LD Macintosh such as the C-MAC (Karl Storz, Tuttligen, Germany) or McGrath MAC (Aircraft Medical, Edinburgh, UK), among others. Also used as a conventional direct laryngoscope. This reduces, at least theoretically, the learning curve needed to use them correctly.

Other advantages common to all of them are the ease of visualization of the glottic structures, which allow to use any type of endotracheal tube (ETT) and the longer duration than the fiberscope, combined with the lowest cost.

The disadvantage is that, even in most of cases CL improves, the introduction of ETT is sometimes difficult and a certain practice is required, so eventually ETT must be performed with a guarantor (contrary to which occurs with angled blades).

2. VL with *Angled Rigid Blade* such as Glidescope (Verathon, Bothell, WA, USA), king vision with no channel blades (KingSystems, www.Kingsystems.com, distributed in Spain by Ambu a/S, www.ambu.es), the McGrath MAC X blade (aircraft medical, Edinburgh, UK), or the C-MAC D blade (Karl Storz, Tuttligen, Germany), among others.

All of them present advantages common to all of them: ease of visualization of glottic structures, allow to use any type of ETT and longer duration than the fiberscope.

The disadvantage is that, although Cormack-Lehane improves in most cases, the introduction of ETT is sometimes difficult.

The lack of a channel in which to put the ETT usually requires a certain practice and, often, it is necessary to preform the ETT with a catcher that provides the same the angulation that has the blade of the VL so as to be able to direct it to the entrance of the glottis.

3. Videolaryngoscopes with *Channel to guide* the ETT such as Airtraq (Prodol Meditec, Vizcaya, Spain, 2005. US Patent No 6,843,769), King Vision with a channeled blade (KingSystems), and the Pentax-AWS-S100 (Pentax Corporation, Tokyo, Japan), among others.

They all have a channel through which the ETT slides for intubation. As the ETT is directed by the channel, we must do any modification of movements on the device and not on the tube.

The tube does not need to be preformed with a stylet and generally enhances the Cormack-Lehane.

6.3. Current scientific evidence

The new optical devices are recommended to improve the management of the airway, both in anesthetic care and in critical patients [41, 42, 45, 46]. In recent years, the role of videolaryngoscopes has been debated, especially its use in the ICU [29, 31, 37, 42, 47–51], where there is a lack of scientific evidence and, in general, intubation is performed in more complicated conditions than in the operating room [52]. However, this evidence is supported in the surgical setting as there are randomized controlled trials (RCTs), meta-analyses, and systematic reviews. Although the environments are different, neither the techniques for the acquisition of competencies, and in one place as in the other, there are situations of unexpected vital commitment and/or deterioration of respiratory and hemodynamic function [7, 21, 41, 53, 54]. Therefore, the results of existing studies in surgical areas can be extrapolated to the field of ICU for many of the above-mentioned plots.

In this sense, Healy et al. published an updated systematic review of Videolaringoscopes in 2012 with the objective of organizing the literature about the effectiveness of modern VL in the OTI and then performing a quality assessment and making recommendations for its use [38].

The comparison of VL with LD was based on three main results: global success, first-attempt success, and successful intubation time.

The vision of the glottis was a desirable result, but since with the VL the intubation can be performed despite having a limited view of it and, on the other hand, a good view of the larynx does not always guarantee a successful intubation, it was not considered a target for the recommendation.

The final recommendations of the study could be summarized in three points:

1. In patients at risk of difficult laryngoscopy, the use of Airtraq, C-Trach, GlideScope, Pentax AWS, and V-MAC is recommended for successful intubation.

2. The use of the Airtraq, Bonfils, Bullard, C-Trach, GlideScope, and Pentax AWS by an operator with reasonable prior experience is recommended for successful intubation in CLD (CL ≥ 3).

3. There is additional evidence to support the use of Airtraq, Bonfils, C-Trach, GlideScope, McGrath, and Pentax AWS after intubation failed by direct laryngoscopy to achieve successful intubation.

Be that as it may, the use of VLs not only improves glottic vision, and in the ICU they also present other advantages such as positive effects on teamwork, communication and knowledge of the situation, as well as on technical skills. The use of VL on the training of residents, with an adjunct that shares their opinion as responsible for intubation seen on the screen, giving advice to help intubation, training nurses of the ICU allowing them to control the effect of the pressure on the cricoid during the sellick, adjusting it as necessary. In addition, the VL is immediately available, which means an improvement in the management of the unexpected DA [37, 55].

A major advantage of standard "*rigid*" VL, like the LD Macintosh, is that they use the same skills as LD, which reduces the need for specific training in VL, while facilitating the training of residents in the management of the airway by LD. In addition, intubation can be recorded for post-event teaching.

The study by De Jong et al., from the Montpellier group, evaluated the McGrath MAC (Aircraft Medical, Edinburgh, Scotland), a VL with a Macintosh type spade that allows intubation using conventional or indirect direct laryngoscopy. The results reported by these authors are similar to other studies, noting that it is easier to visualize the glottis using VL and that fewer attempts are required to achieve intubation. However, although De Jong et al. showed a significant reduction in the incidence of difficult laryngoscopy and/or difficult intubation with VL McGrath MAC (4 vs. 16%) in ICU patients did not provide information on whether or not actual intubation time was shorter [51].

In ICU, where patients are often under a cardiorespiratory compromise, reducing the time the patient is without adequate ventilation/oxygenation is probably more important than the time it takes to visualize the glottis. In the study by Yeatts et al. was found that a shorter time was required to insert an ETT when a conventional direct laryngoscopy was performed [56]. In fact, in this study, an IL with Glidescope (Verathon Médico, Bothell, WA) was associated with prolonged intubation times in trauma patients, with a longer time of hypoxemia and a higher mortality in patients with traumatic brain injury [57]. These results coincide with those of the ICU study carried out by Griesdale et al., who found that intubation with Glidescope VL resulted in lower oxygen saturations [58].

In addition, the study by De Jong et al., from the Montpellier group, evaluated McGrath MAC, a "*mixed*" VL that can be used both to obtain direct and indirect laryngoscopy vision [51]. This prospective study showed that systematic use of a "*mixed*" VL, also termed "*combo VL*" or "*combined VL*", for intubation within a process of quality improvement using an algorithm of airway management significantly reduced the incidence of difficult laryngoscopy and/or difficult intubation.

In the multivariate analysis, the use of a standard laryngoscope was an independent risk factor for difficult laryngoscopy and/or difficult intubation, as was the Mallampati III or IV score and the status of nonexpert operator. On the other hand, in the subgroup of patients with difficult intubation predicted by the MACOCHA score (**Figure 3**), the incidence of difficult

MACOCHA Score Calculation Worksheet	Points
- Factors related to patient	
Mallampati Score III or IV	5
Obstructive Sleep **A**pnoea Syndrome	2
Reduced Mobility of **C**ervical Spine	1
Limited Mouth **O**pening <3cm	1
- Factors related to pathology	
Coma	1
Severe **H**ypoxaemia (<80%)	1
- Factor related to operator	
Non **A**naesthesiologist	1
Total	**12**

Sources: De Jong et al. 2014a; 2013b

M. **M**allampati score III or IV
A. **A**pnoea Syndrome (obstructive)
C. **C**ervical spine limitation
O. **O**pening mouth <3cm
C. **C**oma
H. **H**ypoxia
A. **A**naesthesiologist Non trained

Coded from 0 to 12
0 = easy
12 = very difficult

Figure 3. Macocha score.

intubation was much higher in the standard laryngoscope group (47%) than in the "*mixed*" VL group (0%). These results were in agreement with the previous studies [51].

Cameron et al. perform a study to evaluate the odds of first-attempt success with video laryngoscopy compared with direct laryngoscopy, using a propensity-matched analysis to reduce the risk of bias, for intubations performed in a medical ICU. They accomplish an analysis of prospectively collected data for 809 consecutive intubations performed between 2012 and 2014 in the ICU of an academic tertiary referral center that supports fellowship training programs in pulmonary and critical care medicine [59].

This study comparing video laryngoscopy with direct laryngoscopy as performed by non-anesthesiologist trainees in a medical ICU demonstrates improved first-attempt success associated with video laryngoscopy. Author's findings are clinically significant and consistent with other reports and meta-analyses. These results, in combination with the existing literature on the success of video laryngoscopy and the availability of video laryngoscopy in most academic medical ICUs, suggest that video laryngoscopy should be considered the primary method of laryngeal visualization for intubations performed in ICUs, where there is increased risk of intubation-related complications.

A 2014 meta-analysis found that, compared with direct laryngoscopy, videolaryngoscopy improved glottis view and first-attempt success for orotracheal intubation in ICU [10]. However, both randomized controlled trials (RCTs) and observational studies were included in that study, and evidence from RCTs was limited. In the past months, new RCTs have debated the application of videolaryngoscopy in airway management in ICU [60, 61]. Bing-Cheng Zhao et al. performs a meta-analysis of RCTs to evaluate the effects of video laryngoscopy on first-attempt success and complications related to intubation in ICU patients [50].

Four RCTs enrolling 678 patients were included [60–63], and compared with direct laryngoscopy, videolaryngoscopy did not significantly improve first-attempt success rate (RR 1.17, 95% CI 0.89–1.53). In videolaryngoscopy groups, poor glottis visualization was less common (RR 0.30, 95% CI 0.14–0.64), and incidence of esophageal intubation was lower (RR 0.31, 95% CI 0.11–0.90). However, videolaryngoscopy did not reduce the time for successful intubation and other outcomes, including severe hypoxemia, hypotension, mechanical ventilation duration, and ICU mortality.

Nonetheless, trial sequential analysis showed that the current evidence on the use of videolaryngoscopy is still inconclusive. The prima facie question is whether there may be a type H error due to an inadequate sample size, seeing that there already exists a trend favoring the use of videolaryngoscopy in relation to the primary outcome of successful first-attempt intubation. A previously published meta-analysis of nine studies by De Jong et al. demonstrated the superiority of videolaryngoscopy versus direct laryngoscopy with an odds ratio (OR) of 2.07 (95% CI 1.35–3.16) [10]. Significant heterogeneity exists in the forest plot (P test 73%) with appreciable differences between the operators from inexperienced medical students to critical care medicine experts [50]. Nonanaesthesiologist as operator has been validated to be a risk factor for difficulty in intubation in ICU [64]. The operator's training and experience in comparative studies is, in our opinion, a critical factor which influences reported differences among various intubation devices. Out of the four randomized trials included for the meta-analysis [50], data from Silverberg et al. [61] was excluded for the analysis of time for successful intubation on the grounds of high bias risk (due to suboptimal allocation concealment and randomization strategy). The study by Silverberg demonstrated statistically and clinically significant differences in the time for successful intubation favoring videolaryngoscopy. Non-inclusion may affect the pooled data analysis by Zhao et al. [50]. Curiously, data from the same study was included for pooled analysis of the primary outcome (rate of successful intubation on the first-attempt). Two of the included studies compared the performance of the Glidescope with direct laryngoscopy, and two pooled data sets were included from studies comparing the McGrath videolaryngoscope against direct laryngoscope. Not all videolaryngoscopes are the same and the airway literature distinguishes channeled videolaryngoscopes versus the anteriorly angulated variety versus the Macintosh-like videolaryngoscopes—appreciating peculiar advantages and disadvantages of each. Combining results from all videolaryngoscopes as an entity may have its limitations.

In this regard, Joshi et al. [65] have tried to identify characteristics associated with first-attempt failure at intubation when using videolaryngoscopy in the ICU. They perform an observational study of 906 consecutive patients intubated in the ICU with a video laryngoscope between January 2012 and January 2016 in a single-center academic medical ICU. After each intubation, the operator completed a data collection form, which included information on difficult airway characteristics, device used, and outcome of each attempt.

In this single-center study, there were no significant differences in sex, age, reason for intubation, or device used between first-attempt failures and first-attempt successes. First-attempt successes more commonly reported no difficult airway characteristics were present (23.9%; 95% confidence interval [CI], 20.7–27.0% vs. 13.3%, 95% CI, 8.0–18.8%).

Presence of blood in the airway (OR, 2.63, 95% CI, 1.64–4.20), airway edema (OR, 2.85; 95% CI, 1.48–5.45), and obesity (OR, 1.59, 95% CI, 1.08–2.32) were significantly associated with higher odds of first-attempt failure, when intubation was performed with videolaryngoscopy in an ICU.

In a second logistic model to examine cases in which these additional difficult airway characteristics were collected (n = 773), the presence of blood (OR, 2.73, 95% CI, 1.60–4.64), cervical immobility (OR, 3.34, 95% CI, 1.28–8.72), and airway edema (OR, 3.10; 95% CI, 1.42–6.70) were associated with first-attempt failure [65].

There are important limitations in this study, such that when certain difficult airway characteristics such as blood, vomit, or airway edema could have been known before the intubation attempt or encountered during the attempt, it is possible that operator reporting of these difficult airway characteristics was more common when they were unexpectedly encountered. Moreover, multivariable analyses account for experience of the operator. The generalization of these study results may be limited given the exposure, airway curriculum, and experience of trainees at this institution compared to others.

Nevertheless, the intensive care professional should account for these difficult airway characteristics, blood, cervical immobility, and airway edema, when preparing for endotracheal intubation with video laryngoscopy in addition to standard practices employed to optimize first-attempt success.

Janz et al. [62] evaluates the effect of video laryngoscopy on the rate of endotracheal intubation on first laryngoscopy attempt in a randomized, parallel-group, pragmatic trial of video compared with direct laryngoscopy among 150 critically ill adults undergoing endotracheal intubation by Pulmonary and Critical Care Medicine fellows in a Medical ICU in a tertiary, academic medical center.

The primary outcome was the rate of intubation on first-attempt, adjusted for the operator's previous experience with the intubating device at the time of the procedure. Adjustment for the operator's previous device experience was performed by collecting the number of times the operator had previously used a VL or DL at the time of each intubation event during the trial, such that the adjustment for prior experience with a specific device was updated constantly as the trial progressed.

Videolaryngoscopy improves glottic visualization but does not appear to increase procedural success in unadjusted analyses or after adjustment for the operator's previous experience with the assigned device (OR for video laryngoscopy on intubation on first-attempt 2.02, 95% CI, 0.82–5.02, $p = 0.12$). Secondary outcomes of time to intubation, lowest arterial oxygen saturation, complications, and in-hospital mortality were not different between video and direct laryngoscopy [62].

The results of all of these studies are in contrast with results of prior studies demonstrating improved procedural success with VL [30, 36, 61]. There are several potential explanations for this difference, as that prior study limited to noncritically ill populations [66] may not apply to the patient, operator, and procedural conditions surrounding intubation in the ICU.

A lack of accounting of the experience of the operator at the time of the procedure [30, 36, 49, 61, 67] may also confound the results all of these works.

Several studies have shown that videolaryngoscopy enhances the laryngeal view in patients with apparently normal and anticipated difficult airways [32, 33, 39, 53, 68–70]. And there are a number of possible reasons why improving glottis view with VL does not translate into procedural success. Therefore, these data may not be generalizable to operators using videolaryngoscopes other than the McGrath MAC and direct laryngoscopes with straight blades. And some authors theorize that improving glottic view with VL may only matter to less-experienced operators [62].

The MACMAN trial (McGrath Mac Videolaryngoscope Versus Macintosh Laryngoscope for Orotracheal Intubation in the Critical Care Unit) is a multicentre, open-label, randomized controlled superiority trial published in JAMA [63]. It was a multicenter, randomized, open-label trial, which included all ICU patients that needed orotracheal intubation.

Lascarrou et al. try to determine whether video laryngoscopy increases the frequency of successful first-pass orotracheal intubation compared with direct laryngoscopy in ICU patients. They perform a randomized clinical trial of 371 adults requiring intubation while being treated at 7 ICUs in France between 2015 and 2016, and there was 28 days of follow-up.

The primary outcome was the proportion of patients with successful first-pass intubation. The secondary outcomes included time to successful intubation and mild to moderate and severe life-threatening complications.

The first intubation attempts were made by a nonexpert in 83.8% of patients. There were no difference in first-pass success between the VL (67.7%) and the ML (70.3%) groups (absolute difference, −2.5% [95% CI, −11.9% to 6.9%]; p = 0.60. These results were sustained even after adjusting for operator expertise and MACOCHA score.

The proportion of first-attempt intubations performed by nonexperts (primarily residents, n = 290) did not differ between the groups (84.4% with videolaryngoscopy vs. 83.2% with direct laryngoscopy; absolute difference 1.2% [95% CI, −6.3% to 8.6%]; p = 0.76). The median time to successful intubation was 3 min (range, 2–4 min) for both videolaryngoscopy and direct laryngoscopy (absolute difference, 0 [95% CI, 0 to 0]; p = 0.95). Videolaryngoscopy was not associated with life-threatening complications (24/180 [13.3%] vs. 17/179 [9.5%] for direct laryngoscopy; absolute difference, 3.8% [95% CI, −2.7% to 10.4%]; p = 0.25). In post hoc analysis, videolaryngoscopy was associated with severe life-threatening complications (17/179 [9.5%] vs. 5/179 [2.8%] for direct laryngoscopy; absolute difference, 6.7% [95% CI, 1.8% to 11.6%]; p = 0.01) but not with mild to moderate life-threatening complications (10/181 [5.4%] vs. 14/181 [7.7%]; absolute difference, −2.3% [95% CI, −7.4% to 2.8%]; p = 0.37).

The main reason for intubation failure in the ML group was inability to see the glottis, and in the VL group was failure of tracheal catheterization.

The ability to see the glottis is related to the expertise with the procedure and the equipment you are using, either way, since the groups were balanced regarding the physicians' expertise, the difference found between the two groups here might be because it is easier to visualize the glottis with the VL. The failure of tracheal catheterization, 70.7% (VL) vs. 23.5% (ML), can be explain with the learning curve or because they study a non-channeled VL. Eye-hand coordination, especially when looking through a monitor, is not learned with a few training sessions. Stratified by center and "*the status of expertise or nonexpertise of the individual performing intubation*". Unfortunately, the expert defying criteria did not include any experience with VL, and a good explanation for this difference is the lack of experience with the VL device besides the absence of channel in the blade.

Several studies comparing videolaryngoscopy with direct laryngoscopy have demonstrated improved rates of first-attempt success in the operating room, emergency department, trauma unit, and simulation laboratory, as well as during active cardiopulmonary resuscitation [56–58, 71–80]. Data comparing videolaryngoscopy with direct laryngoscopy on first-attempt success in the ICU are limited to a small number of observational studies [30, 36, 81–83], a meta-analysis of those studies [10], and some randomized controlled trials [60, 61].

Randomized controlled trial data comparing video laryngoscopy with direct laryngoscopy in the medical ICU are limited in number and external validity, especially for intubations performed by nonanesthesiologists.

6.4. Limitations

Videolaryngoscopes have among their disadvantages the cost, which mainly restriction access in areas outside the operating room. Devices need to be connected to the mains or batteries, and those that have an external monitor connected by cable may be little "*portable*".

Because they provide an indirect image, the blood, secretions, and fogging of the lens obscure the image.

The fogging can be prevented by pre-aspirating the pharynx, or by preheating or applying specific solutions to the distal lens if the device does not have a concrete anti-fogging system (such as GlideScope, Airtraq, King Vision, etc.).

Like any other device, VLs require a learning curve. Those who have a shovel similar to that of the Macintosh (without a canal) need a transglottic device (guarantor, Frova, Eschman, etc.), inserted through a technique that must be learned since they can generate traumatisms on the soft palate during its introduction. On the other hand, if the operator cannot properly position the device-channel blade, the tube can be guided into the esophagus. When this occurs, while maintaining a good vision of the glottis and the patient remains stable and well oxygenated, we can try to solve the problem by a light movement of the device (**Figure 4**) or the ETT (**Figure 5**), which will help guide the ETT and achieve successful intubation.

6.5. Complications

All of these devices allow an optimal visualization of the glottic anatomy, but sometimes the maneuvers required for intubation involve greater complexity because of the difficulty in orienting the ETT.

For this reason, specific guides and catheters have been designed for intubation.

Nevertheless, in parallel with the clinical use of these devices, complications have been described.

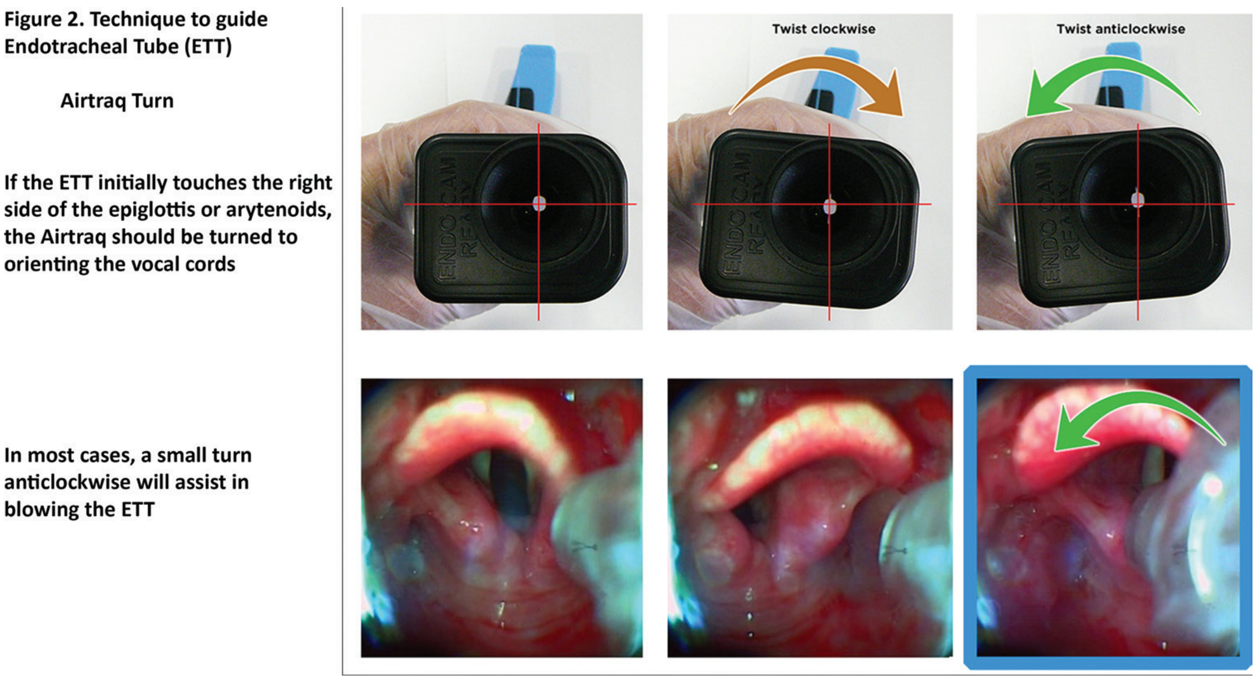

Figure 4. Technique to guide endotracheal tube (ETT).

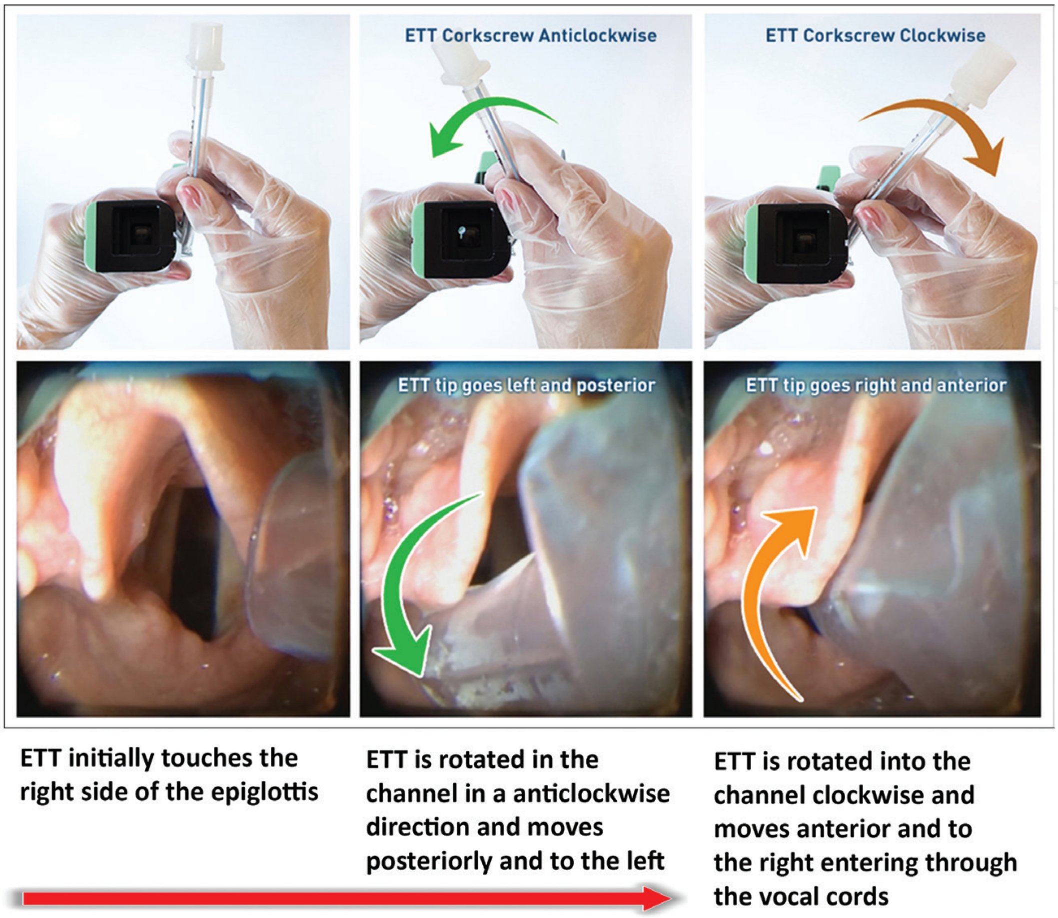

Figure 5. Technique for orienting the endotracheal tube (ETT).

Thus, lacerations of the glottic mucosa, vocal cord lesions, subluxations of arytenoids, and supracarinal tears are some of the complications encountered with the use of these new devices.

6.6. Practical approach to videolaryngoscopy

If we decide to use any device in our patients we think about practical approach of this device and not only in theoretical applications. In the case of videolaryngoscopes, we can raise doubts about how is the procedure different of direct videolaryngoscopy?

When we will perform the intubation, we must take into account that videolaryngoscope intubation is quite different than traditional direct laryngoscopy. The videolaryngoscope blade must be inserted into the middle of the mouth and rotated around the tongue in order to line up the camera lens with the larynx.

Always insert the videolaryngoscope midline into the mouth looking at the patient until its tip has passed the palate.

Once the blade has turned the corner into the pharynx, look at the monitor while glancing at your patient to optimally position the blade.

There are three types of blade. The non-channeled blades can be equal to the traditional direct laryngoscope blade or can be angled. This angle used to be 60° or similar, and make impossible direct visualization of the glottis.

The third type is the channeled blades that have a channel to lead the ETT toward to the glottis.

We have to be very clear that videolaryngoscopes allow a view of the entrance of glottis independent of the line of sight, especially those that have angled blades, but if we use a non-channeled and non-angled blade, it will be equal to the traditional direct laryngoscope blade, and we have a similar glottic view if we perform a direct laryngoscopy.

Other important question is about patient head position regard. One of the most important features of these devices, particularly angled blades, is that the head and neck should be in extreme sniffing position or in a neutral position during all the intubation intent. We can see indirectly glottis, independent of the line of sight, because the image sensor is in the distal part of the blade. This give us a panoramic view of the glottis, without the need to "align the axes", thus avoiding hyperextension of the head.

But, if we do not need to move head's patient, do we still lift the jaw upward like in direct videolaryngoscopy? In clinical practice, Cormack-Lehane grade obtained with videolaryngoscopes use to be one or two at last in 99% of the cases. But, this view not guarantees the success of intubation, which is relatively frequent in videolaryngoscopes that have a curved leaf, especially during the learning stage. This difficulty in achieving intubation despite the correct exposure of the larynx even in expert hands may be finally impossible.

So, in practice, sometimes perform the traditional maneuvers as lift the jaw upward, BURP maneuver, wear the epiglottis or move carefully the videolaryngoscope can facilitate the intubation.

As stated above, usually all patients had grade 1 or 2 Cormack-Lehane views (grade 1: full glottic view; grade 2: partial glottic view; grade 3: epiglottis visible but no glottic view; and grade 4: epiglottis not visible) with videolaryngopscopes. However, achieving CL grade 1 laryngoscopy in videolaryngoscopy does not guarantee the success of OTI, which is relatively frequent in VLs that have a curved leaf.

There have been a number of maneuvers suggested to increase the success of passing the endotracheal tube when glottic visualization is excellent and the tube is not easily passed using usual methods.

With non-channeled blades, once the blade is positioned with the larynx in view (as we explain in the previous point), we insert the ETT along the right side of the blade. Even though the magnificent view of the larynx on the monitor at this point, we must remember that the larynx is not in the direct line of sight.

Therefore, a properly curved stylet must be used to guide the endotracheal tube into the larynx. Unlike the typical "hockey-stick" shape used during direct laryngscopy and in the standard videolaryngoscope blades, the stylet should match the curve on the angled blades.

If it is being used a standard stylet, it must be placed into the ETT and then mold it against the blade so that the curves match. The ETT can leave into the sleeve to keep it clean.

Because a standard disposable stylet is so malleable, occasionally it will straighten during insertion, especially if the oral space is tight. This leads to the scenario of being able to see the larynx and not being able to "get there". There are specific stylets, some of them nondisposable, which are preconfigured to the correct curve of their videolaryngoscope. Some of them are very stiff and can potentially damage pharyngeal structures, so that they must pull back slightly before fully inserting the ETT into the trachea.

Regardless of which stylet you are using, insert the endotracheal tube with the curve aimed toward the right side of the mouth, under direct vision until to see it on the monitor.

At this point rotate the tube back toward the midline, and aim it at the glottic opening.

If the mouth is small, it can be helpful to insert the ETT into the mouth first, slide it far to the right side of the mouth, and then insert the videolaryngoscope non-channeled blade midline.

To avoid lesions, it is mandatory to look at the patient during insertion of the ETT as described above until its tip has passed out of view beyond the tonsillar pillars. Only after the tip of the ETT has turned the corner into the pharynx should you look at the monitor, otherwise you can injure teeth, lips, tongue, and pharyngeal structures. Manipulate the tip of the tube through the glottis, and then pause to withdraw the stylet 2–3 cm. to effectively soften the tip of the ETT. Advance the ETT into the trachea looking at the monitor.

Channeled videolaryngoscopes have the advantage of orienting the ETT toward the trachea, allowing directed intubation with a little manipulation of the airway.

After successful intubation, remove the videolaryngoscope looking at the patient, not the monitor.

And, finally, we must think about regurgitation. Cricoid pressure, also named Sellick maneuver, is a standard anesthetic maneuver used to reduce the risk of aspiration of gastric contents during the induction of general anesthesia, applied after induction, in the period between loss of consciousness and placement of a cuffed tracheal tube. This is also a standard component of a rapid sequence induction technique. Cricoid pressure has been shown to prevent gastric distension during mask ventilation too.

A correct Sellick maneuver should be applied with a force of 10 N when the patient is awake, increasing to 30 N as consciousness is lost. These pressures occlude the esophagus and prevent aspiration during intubation, but often resulting in worsened glottis view and complicate intubation.

If initial attempts at videolaryngoscopy are difficult during rapid sequence induction, cricoid pressure should be released. This should be done under vision and suction available and, if we see regurgitation, cricoid pressure should be immediately reapplied.

7. Optimization of processes

In most cases, there is sufficient time to improve the intubation conditions, to perform an initial assessment and to evaluate the risk of intubation, to verify the availability of material, inductive agents and to plan alternatives.

Even so, on other occasions, the urgency of intubation in ICU is extreme (cardiorespiratory arrest, polytrauma, coma, etc.), and OTI should be performed in an optimal attempt of intubation with little time to optimize the patient.

Critical patient may present, mainly, hypoxemia, severe metabolic acidosis, hypotension, and right ventricular insufficiency [9, 16, 19, 20], with a degree of hemodynamic instability resulting in a low cardiopulmonary reserve, in addition to a full stomach, etc., and the implementation of a package of measures for intubation can reduce the incidence of life-threatening complications from 32 to 17% ($p = 0.01$) during intubation (biblioUCI46). This package of measures should consist of 10 key points (**Table 2**).

Of these recommendations, six have individually demonstrated their benefit, both in anesthetic practice and in critical care (noninvasive mechanical ventilation [NIM], the presence of two operators, rapid sequence intubation [drugs and Sellick maneuver], capnography, and protection ventilation pulmonary).

The presence of a second operator in crisis situations has been shown to reduce the complications associated with the OTI procedure such as esophageal intubation (0.9% vs. 3.4%), traumatic intubation (1.7% vs. 6.8%), bronchoaspiration (0.9% vs. 5.8%), tooth damage (0% vs. 1.0%), and selective intubation (2.6% vs. 7.2%). The overall rate of complications also decreased significantly (6.1% vs. 21.7%, $p < 0.0001$) [89].

Prior to intubation
1. Presence of two operators.
2. Perform a loading of fluids (500 ml of isotonic saline or 250 ml of colloid) in the absence of cardiopulmonary edema.
3. Preparation of maintenance sedation.
4. Preoxygenation for 3 min with noninvasive mechanical ventilation (NIMV) in case of acute respiratory failure (100% FiO_2, ventilatory support pressure between 5 and 15 cm H_2O, to obtain an expiratory volume between 6 and 8 ml kg^{-1} and a PEEP of 5 cm H_2O).
During intubation
Rapid sequence intubation (RSI): etomidate 0.2–0.3 mg kg^{-1} or ketamine 1.5–3 mg kg^{-1}, combined with succinylcholine 1–1.5 mg kg^{-1} in the absence of allergy, hyperkalemia, severe acidosis, acute or chronic neuromuscular disease, burn patient of more than 48 h evolution and spinal cord trauma. Rocuronium bromide (rocuronium) 0.9–1.2 mg kg^{-1} may be used when succinylcholine is not indicated [84–87].
5. *Sellick maneuver* [88].
Post-intubation
6. Immediate confirmation of the position of the ETT by *capnography*.
7. Noradrenaline if diastolic BP remains <35 mmHg.
8. Initiate long-term sedation.
9. Initiate *lung protection mechanical ventilation*: tidal volume 6–8 ml kg^{-1}. According to ideal weight, PEEP <5 cm H_2O, and respiratory frequency between 10 and 20 resp./min, FiO_2 100% for a plateau pressure <30 cm H_2O.

Table 2. Package of measures for intubation in ICU.

Therefore, prior to anesthetic induction, at least the presence of two operators, water overload and preoxygenation with NIMV is recommended for 3 min in case of acute respiratory failure.

7.1. Patient's preparation

Before the AM should be prepared the basic material:

- Ventilation: facial mask of adequate size, manual resuscitator, oropharyngeal cannula.
- Intubation: laryngoscopes, videolaryngoscopes, endotracheal tubes, extraglottic devices (such as FROVA or an introducer of Eschmann).
- Position: the position of the patient is an important factor and limits the reduction of functional residual capacity. Several studies have shown that prior oxygenation in the semi-seated position or with the head at 25° can achieve greater PaO_2 [90, 91].
- Vacuum cleaner.
- Medication.

In the case of expected intubation difficulty, there should be a practically immediate availability of advanced AM material with different rescue devices of ventilation and intubation difficulty, as well as a Coniotomy cannula in the event of an eventual CICO situation.

The ICU should have prepared a difficult airway trolley, similar to those that can be found in the surgical blocks [1] (**Figure 6**).

7.2. Preoxygenation

Acute hypoxemic insufficiency is the main cause of intubation in the ICU.

One-third of patients had severe arterial desaturation ($SatO_2 < 80\%$) during intuation manevers.

Figure 6. Reanimation difficult airway trolley examples. Left, Infanta Leonor University Hospital. Right, Getafe University Hospital, Madrid, Spain.

Hypoxemia may favor the complications observed during intubation such as arrhythmias, myocardial ischemia, cardiac arrest, and hypoxia in the brain.

Preoxygenation is the administration of 100% FiO_2 before induction. This maneuver aims to displace the alveolar nitrogen (N_2) by replacing it with oxygen (denitrogenation), in order to obtain an intrapulmonary O_2 reserve that allows the maximum apnea time with the lowest desaturation [92–96].

Traditional preoxygenation, performed with ventilation at current volume with Mapleson circuit and well-sealed facial mask, using a fresh gas flow of 5 L/min. of 100% oxygen for 3–5 min [94], is insufficient in the critical patient [97]. And only 50% of these patients will experience an increase of their PaO_2 higher than 5% compared to their baseline values after conventional preoxygenation for 4 min [98].

In all ICU patients, preoxygenation should be performed using a NIMV with PEEP 5–10 cm H_2O + PS 5–15 with FiO_2 100%, a management that has been shown to prevent patient desaturation during the procedure [98].

The mean pressure on AM will lead to alveolar recruitment, with the temporary reduction of intrapulmonary shunt [99] and an improvement in oxygenation. However, when this positive pressure is removed for OTI there is a risk of alveolar dis-reclusion, which will cause rapid desaturation.

Maintenance of continuous positive pressure during intubation with the use of a nasal mask has been shown to be beneficial in the operating room to patients with hypoxemic respiratory insufficiency and may be useful in ICU [100]. This apnea (or apneic) oxygenation is based on the alveolar pressure exerted by the blood circulation in the alveoli at slightly sub-atmospheric levels, generating a negative pressure gradient.

Another option is the high-flow nasal cannula (CNAF), a system that can provide up to 100% warm and humidified FiO_2 at a maximum flow of 60 L/min. [101].

This system allows an increase in CO_2 clearance due to better pharyngeal space clearance [102], in addition to the generation of a continuous positive pressure in flow-dependent AM (CPAP) (up to 7.4 cm H_2O to 60 L/min), with the reduction of respiratory resistance and maintenance of alveolar opening.

7.3. Recruitment maneuver

Idea of NIMV use during preoxygenation is to recruit lung tissue available for gas exchange: "*open the lung*" with PS, and "*keep the lung open*" with PEEP.

The combination of preoxygenation/denitrogenation (with FiO_2 100%) and the apneic period associated with the OTI procedure can dramatically decrease the pulmonary ventilation volume ratio, causing atelectasis.

Recruitment maneuver (RM) consists of a transient increase in inspiratory pressure, and there are several possible maneuvers such as applying a CPAP of 40 cm H_2O during 30–40 s immediately after the OTI. When compared with not do, RM is associated with a higher PaO_2 (with FiO_2 100%) 5 min (93 ± 36 vs. 236 ± 117 mmHg) and 30 min (39 ± 180 vs. 110 ± 79 mmHg) after intubation [103, 104].

7.4. Hypotension

Peri-OTI hypotension is a risk factor for adverse events, including cardiorespiratory arrest related to the management of AM, and up to 30% of critically ill patients may present post-OTI cardiovascular collapse [21, 54, 105–107].

Systolic blood pressure (SBP) <70 mmHg complicates 10% of intubations in ICU patients [9, 54, 106, 107], and when the patient has a preinduction gravity HR/SBP > 0.8, hemodynamic optimization should be performed pre-OTI and use inducing drugs with little response.

In responder patients, resuscitation with volume [108–110] can be made, while in the nonresponders, a perfusion of noradrenaline will be initiated [111, 112].

If pre-OTI resuscitation is not feasible due to the critical situation of the patient, vasoactive drugs will be prepared for bolus administration in order to maintain blood pressure during OTI and subsequent resuscitation. Although there is insufficient evidence, adrenaline diluted at a concentration of 1–10 mcg mL^{-1}, to be administered in boluses of 10–50 mcg, may be most indicated because of its inotropic effect [16, 109, 110, 113, 114].

In patients who are not in shock but exhibit a transient drop in post-OTI blood pressure due to the vasodilatory effects of induction agents or the onset of positive pressure ventilation, diluted phenylephrine at a concentration of 100 mcg mL^{-1} will be administered in boluses at 50–200 mcg [16, 109, 110].

7.5. Severe metabolic acidosis

When acidemia develops from respiratory acidosis, it can be corrected rapidly by increasing alveolar ventilation. However, when acidemia depends on metabolic acidosis, maintenance of acid-base homeostasis depends on compensatory respiratory alkalosis based on alveolar hyperventilation.

In situations of severe metabolic acidosis such as diabetic ketoacidosis, poisoning salicylate, or severe lactic acidosis, the patient may not be able to make an alveolar hyperventilation that achieves buffering generated organic acids with a worsening acidosis [9, 16, 19, 20, 105, 115].

When OTI is required in these patients, even a brief apnea time can lead to a significant drop in pH given the loss of respiratory compensation that was already insufficient.

Therefore, OTI should be avoided in patients with severe metabolic acidosis in whom adequate ventilation with the ventilator cannot be ensured, and NIV can be used to adequately support respiratory work until correction of underlying metabolic acidosis.

If the OTI cannot be delayed, getting the patient to maintain spontaneous ventilation becomes a critical action during intubation and mechanical ventilation, as this will allow the patient to maintain their own minute ventilation. For this, agents with a low probability of generating apnea should be used. In addition, rapid sequence intubation should be avoided if possible, and if deemed necessary, a short-acting neuromuscular blocker such as succinylcholine should be used.

Once OTI is achieved, a ventilator mode should be chosen that allows the patient to establish and maintain their own minute ventilation to maintain respiratory compensation better.

7.6. Right ventricular failure

The main function of the right ventricle and pulmonary circulation is gas exchange. Under normal conditions, these are a low pressure and high-volume system which, in addition, must dampen the dynamic changes in volume and blood flow resulting from breathing, positional changes, and changes in left ventricular cardiac output. The adaptations needed to meet these conflicting requirements result in reduced compensation capacity in the event of a rise in afterload or pressure [105, 113, 116].

The failure of the system generates right heart failure, so that the right ventricle becomes unable to meet the demands, dilating, retrograde flow, decreased coronary perfusion and, ultimately, systemic hypotension and cardiovascular collapse [107, 110, 117].

When a patient with right heart failure requires OTI, increased afterload and decreased preload associated with invasive mechanical ventilation often leads to this cardiovascular collapse [21, 54, 105, 107, 113, 118].

In these patients, we should try to achieve pre-OTI hemodynamic optimization, including reduction of afterload with inhaled pulmonary artery vasodilators such as inhaled nitric oxide (INO) [119] or inhaled epoprostenol (Flolan) [113, 120].

In addition, good preoxygenation due to the reduction of intrapulmonary shunt [99], as well as apneic oxygenation [98, 106] will be essential, as well as avoid hypercapnia and high alveolar pressures, because they lead to vasoconstriction.

8. Critical airway management algorithm

As in the surgical setting, in order to limit the incidence of serious complications during OTI in the ICU, the entire process (pre-, peri-, and post-intubation) should be guided by protocols oriented to patient safety [2, 46, 121–124].

This critical AM algorithm will be based, firstly, on the outcome of the assessment of the difficulty of intubation according to the MACOCHA score [51] (**Figure 7**).

Always check the availability of the equipment for the AM and an eventual DA before the OTI. And, in the case of desaturation <80% during the procedure, the patient will be ventilated.

In the case of failure of intubation and ventilation, emergency ventilation through NIMV through a SAD allowing intubation [125] will be performed.

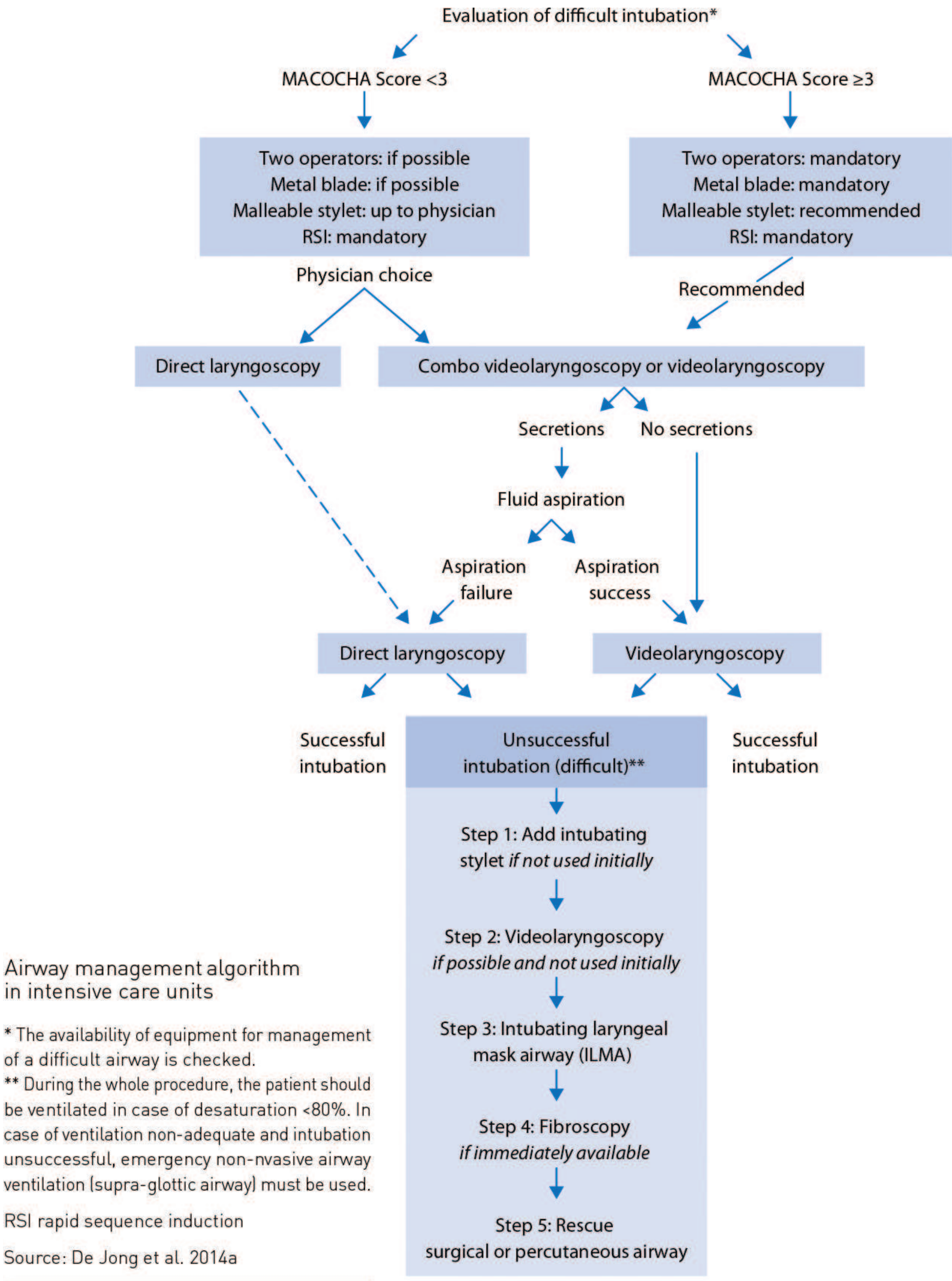

Figure 7. Macocha score protocol.

Two operators should always be present, especially if an AD with a MACOCHA score ≥3 is predicted, an extraglottic device (e.g. FROVA or an Eschmann introducer) should be used, and a rapid sequence induction be performed.

The use of a VL is also recommended in cases of difficult intubation. Nonetheless, in cases of abundant secretions, even after aspiration, direct laryngoscopy will be preferable to videolaryngoscopy.

Finally, in case of failure of intubation, an extraglottic device (e.g. FROVA or an Eschmann introducer) will be used first, followed by a VL if it was not initially used, rescue with a supraglottic airway device (SAD) that allows intubation, fiber optic bronchoscopy (FOB) and, at last, percutaneous or surgical rescue in situations of failure of intubation, ventilation, and oxygenation (CICO).

8.1. "*Not seemingly difficult*" airway management

It will be those patients who present a MACOCHA score <3.

The R rapid sequence induction (RSI) SI techniques are indicated in these cases, among others, in the ICU, hospital emergency services and out-of-hospital emergencies.

8.1.1. Rapid sequence intubation

The purpose of the RSI is to make emergency intubation easier and safer, and thus increase the success rate and reduce potential complications.

There is no single RSI technique due to its numerous indications, so the choice of the drug and the regimen of administration will be conditioned, not only by the reduction of the risk of aspiration and the facilitation of intubation but also by the characteristics of patient [88, 115, 126, 127]. However, the key elements that remain in all RSI protocol are:

- Preoxygenation/denitrogenation to prolong apnea time.
- Prevention of hypoxia and hypotension during induction and intubation.
- Use of a cuffed ETT, and capnographic confirmation of the placement of the tube.

In spite of the lack of a single RSI technique, the main steps could be summarized in [85, 88, 126, 127]:

- Valuation, planification, and preparation.
- Preoxygenation.
- Premedication.
- Induction and relaxation.
- Application of the Sellick maneuver.
- Laryngoscopy.

- Intubation. The RSI should allow us to intubate in a time no longer than 60 s from the administration of inducing drugs.
- Checking the placement of the ETT.

8.2. The anticipated difficult airway

Apnea following induction and neuromuscular relaxation may lead to rapid desaturation in the critical patient, if not in severe complications. In patients with previously DA [6, 40, 128, 129] or in those who were suspected according to a MACOCHA score ≥ 3, awake intubation would represent a valid option from the point of view of safety of the procedure [23, 29, 123, 130–133].

This intubation with the awake patient can be performed with a noninvasive technique or with an invasive technique (surgical or percutaneous), and among its advantages is that, by maintaining muscle tone, permeability of the airway and spontaneous ventilation, awake patients are easier to intubate because inducing general anesthesia tends to shift the larynx anterior.

The prerequisites for awake intubation in the ICU are:

- Previously difficult airway scenario or positive predictive signs (MACOCHA score ≥ 3).
- Patient cooperation.
- Equipment familiar with awake intubation techniques.
- Adequate AM preparation.

Contraindications:

- Human team inexperience.
- Negative of the patient.
- Allergy to local anesthetics.
- Hemorrhage in oropharyngeal cavity.

8.3. Difficult airway rescue

Before an intubation failure, we can find two possible scenarios:

- *Oxygenation with adequate face mask*: insisting repeatedly on a technique that has not resolved the situation will increase the risk of complications. Therefore, change to an alternative device (e.g. MCcoy blade), use an extraglottic device, use a VL, or a SAD intubation device.
- *Unsuitable oxygenation with face mask*: given the limited period of safe apnea of the critically ill patient, oxygenation, and not intubation, is the absolute priority in this scenario.

  There are different SAD that have been used to rescue ventilation with a difficult facial mask. The usual in ICU after ensuring oxygenation is that endotracheal intubation is necessary, so it is recommended to have some of the SAD that allow intubation through it [3].

  In the case of failure, a CICO scenario will be declared, the worst of the possible scenarios.

8.4. Can't-intubate-Can't-oxygenate scenario

CICO scenario is the end of the algorithms, and always constitutes a medical emergency that forces to explore an alternative plan based on transtracheal access, either through a percutaneous cricothyrotomy (choice for its speed), a surgical tracheotomy or through retrograde intubation.

This situation is reached when the attempt to AM had failed through tracheal intubation, facial mask ventilation, and a SAD. At this point, if the situation is not resolved quickly, hypoxic brain damage and death will occur.

The key points of the non-intubatable/non-oxygenable AM plan are:

- The CICO scenario must be declared and proceed to anterior neck access.
- A didactic technique has been described using a scalpel to promote standardized training.
- Placing an endotracheal balloon tube through the cricothyroid membrane facilitates normal minute ventilation with a standard ventilation system.
- High-pressure oxygenation through a fine cannula is associated with increased morbidity.
- All operators must be trained in performing a surgical approach.
- Training should be repeated at regular intervals to ensure that skills are not lost.

8.5. Adequate staff—adequate material—adequate procedure

Through the training program of those specialists who develop their professional activity in ICU must be guaranteed the acquisition of skills in critical patient's advanced airway management (**Figure 8**).

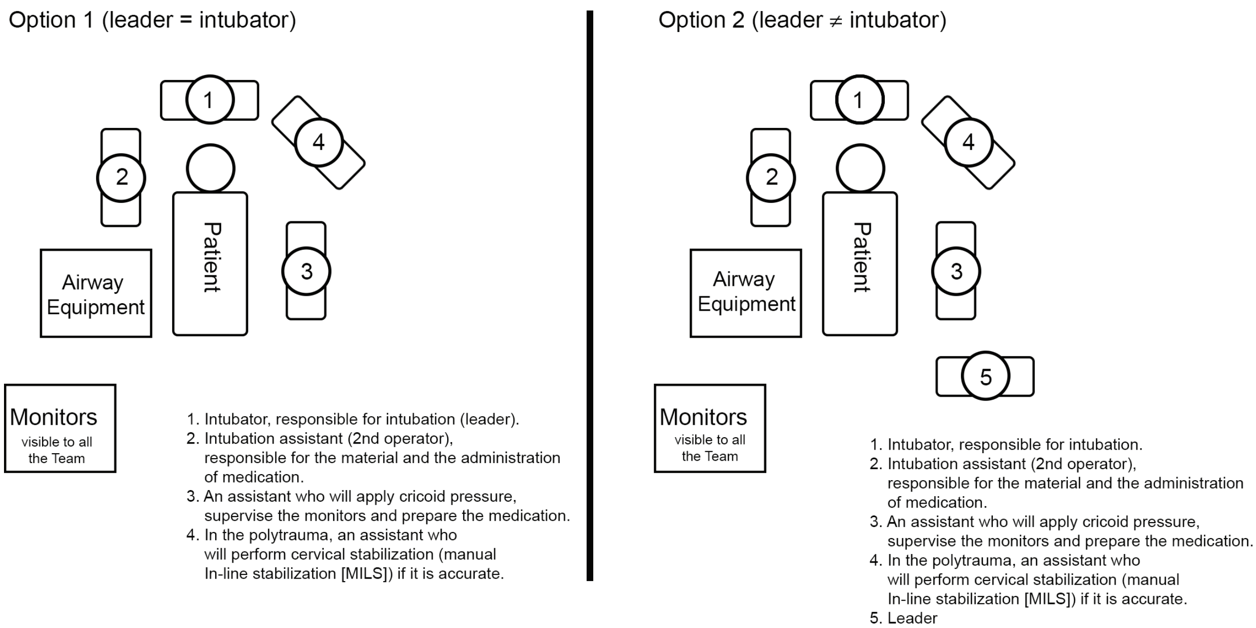

Figure 8. Teamwork, roles, goals and communication.

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Those responsible for the training of each service should develop training programs based on simulation to maintain competencies with different devices: direct laryngoscopy, extraglottic devices, supraglottic devices, videolaryngoscopes, fiber optic bronchoscopes and cricothyrotomy set.

Also, each ICU should have immediate access 24 h a day to a difficult airway trolley that must include the same devices that the one usually available in the operating room.

9. Conclusions

Tracheal intubation in the critical patient is always potentially dangerous. Critically ill patients with acute respiratory, neurological, or cardiovascular failure requiring invasive mechanical ventilation are at high risk of difficult intubation and have organ dysfunctions associated with complications of intubation and anesthesia such as hypotension and hypoxemia. The complication rate increases with the number of intubation attempts. Videolaryngoscopy improves elective endotracheal intubation.

Every professional in ICU should have a basic knowledge about airway management, be familiar with algorithms to handle possible complications, and know correct use and interpretation of capnography. The algorithms that are usually handled by anesthesiologists in our routine clinical practice are not always useful in ICU because they contemplate alternatives such as awakening the patient or postponing the procedure that cannot be applied in a critical/emergency situation. The implementation of an intubation protocol in the ICU can contribute to significantly reduce the immediate severe complications associated with this procedure.

Airway management of patients admitted to the ICU is a challenge. New videolaryngoscopes have been proposed to improve management, but most studies comparing videolaryngoscopes with a standard direct laryngoscope (DL) have been performed in operating rooms. Therefore, the role of videolaryngoscopy in the ICU is still discussed, where there is a lack of scientific evidence and intubation conditions are worse than in the operating room. The Montpellier group has proposed and implemented a package for intubation care in its ICU which includes, among others, the use of two operators, fluid overload, preoxygenation, and, above all, the rapid detection of the position of the ETT by capnography. Including the use of videolaryngoscopy in this package, as described by De Jong et al. [51], the safety of tracheal intubation could be further improved.

The overall impact of VL on the anesthetic literature is weighed due to marked heterogeneity in the patient population, devices studied, operator experience, and confusion including manikin studies. While VL improves the ease of obtaining a view of the larynx, insertion of the ETT may be more difficult. VL may reduce the number of failed intubations, particularly among patients presenting with a difficult airway. They improve the glottic view and may reduce laryngeal/airway trauma. Currently, no evidence indicates that use of a VL reduces the number of intubation attempts or the incidence of hypoxia or respiratory complications, and no evidence indicates that use of a VL affects the time required for intubation [134].

The study of VL in the ICU is difficult for similar reasons, although they are increasing in popularity [10, 36]. However, there is a need for randomized controlled trials (RCTs) of VL vs. DL in the ICU [31], the truth is that the use of VL in ICU is so widespread that such studies are impractical. A RCT could help determine which devices are most useful, and could study the impact of VL on both technical and human factors [135].

If randomized controlled trials demonstrating a benefit of videolaryngoscopy are designed in the future, it could become a new standard for tracheal intubation in the ICU, particularly in educational institutions, where tracheal intubations are often performed by residents in training.

Nevertheless, the introduction of videolaryngoscopy in the ICU should always be accompanied by formal training programs in the management of the DA and simulation using manikins with the specific device [47, 71, 121, 136, 137].

Best way to avoid the serious consequences associated with a DA is the constant preparation by all those who could be able to handle it, an adequate prior assessment of the patient and the capacity to face this situation with the different rescue alternatives, from the use of SAD, VL, and flexibility in the use of the FOB, to the management of cervical surgical neck access.

Finally, we must implement the capnography in the ICU, so that the capnograph will be used in every intubation maneuver in the critical patient. Capnography should be monitored continuously in all critical intubated patients requiring assisted ventilation, and all ICU staff should be trained in the interpretation and recognition of abnormal capnography tracings.

In summary, if we consider the latest data, exclusive use of VL in out-of-OR airway management, or disdain them, appears premature, and we agree with the authors that future research would be necessary to demonstrate the safe utility of videolaryngoscopy in the ICU context. Even though it is surely the future to follow.

Author details

Eugenio Martinez Hurtado[1]*, Miriam Sanchez Merchante[2], Sonia Martin Ventura[3], Maria Luisa Mariscal Flores[3] and Javier Ripolles Melchor[1]

*Address all correspondence to: eugeniodaniel.martinez@salud.madrid.org

1 Department of Anaesthesia, Intensive Care Medicine and Pain Medicine, Hospital Universitario Infanta Leonor, Madrid, España

2 Department of Anaesthesia, Intensive Care Medicine and Pain Medicine, Hospital Universitario Fundación Alcorcón, Madrid, España

3 Department of Anaesthesia, Intensive Care Medicine and Pain Medicine, Hospital Universitario de Getafe, Madrid, España

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