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Prehospital Airway Management

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1. Introduction

Correct airway management and the maintenance of its patency is an essential skill of the health-care team which intervenes at the prehospital scene of emergencies. Airway patency is crucial in ensuring valid oxygenation and good ventilation in critical patients. Up until now, there has been a general consensus in the scientific world on this.

Recently, however, various different works have been published which have cast doubt on the real efficacy of tracheal intubation, a maneuver which is considered to be the gold standard in airway management. In some cases the management of prehospital tracheal intubation has been attributed to potentially worsening the critical patient's final outcome. Unfortunately, an analysis of prehospital airway management studies, especially the more recently published articles, has created more questions than answers.

Significant difficulties have been recorded in the collecting of high quality data in the prehospital setting. This has been mainly due to the fact that it is a notoriously complicated field and often impossible, for ethical reasons, to design randomized surveys which can be controlled in double blind studies. To this we can also add that it is often necessary to recruit a large number of patients in order to obtain sufficient statistical power to demonstrate the effect on the outcome.

Nevertheless, here we will try to provide some answers to the open questions regarding prehospital airway management and propose a rational approach method.

2. Prehospital airway management: open questions

Tracheal intubation is universally accepted as being the gold standard in ensuring airway patency.

There are several advantages:

1. it provides the best ventilation
2. it protects against pulmonary aspiration
3. it permits the aspiration of secretions

In terms of efficacy, however, the question we should ask is: does successful prehospital endotracheal intubation improve survival in critically ill patients? We can try to provide answers to this question by introducing some key elements.

2.1 Useful definitions

We report some definitions used by Italian Society of Anaesthesiologists (Petrini et al, 2005).

a. Difficult airway control

Airway control difficulty is defined as ventilation difficulty (using either face mask or extraglottic devices) and/or intubation difficulty with standard equipment (curve blade laryngoscope and simple endotracheal tube).

b. Difficult ventilation

Difficult mask ventilation occurs whenever the required tidal volume cannot be administered to the patient without any airway device or external help (i.e. airway or three-hand face mask ventilation), standard procedure withdrawal (i.e. face mask switched for any extraglottic device) or intubation (i.e. failure of the extraglottic device).

c. Difficult intubation

Difficult and/or impossible intubation is defined as a maneuver performed with a correct head position and external laryngeal manipulation resulting in: a) difficult laryngoscopy (in a wide definition); b) necessity of repeated attempts; c) necessity of no standard devices and/or procedures; d) withdrawal and procedure replanning.

d. Difficult laryngoscopy

Difficult laryngoscopy is defined as the impossibility of obtaining a view of the vocal cords even after the best external laryngeal manipulation.

2.2 Critically ill patients continuity of care

The general objective of an “emergency system” is to guarantee a diagnostic-therapeutic pathway from the scene of the event, where the prehospital team ensures qualified treatment, to the Emergency Room. When we talk about continuity of care, this is precisely what we mean. The conditions necessary for appropriate treatment at the scene of the event, in relation to the complexity of the situation which the emergency team is faced with, is an effective, multi-professional and multi-disciplinary collaboration. It is necessary to consider that different elements can condition the strategy of the intervention and the quality of the treatment administered in the prehospital setting.

In particular, we must bear in mind:

- the clinical competence and the experience of the health-care team (Timmermann et al, 2006; Sollid et al. 2008)
- their technical abilities
- the non-technical skills of the emergency team (teamwork)

Despite its accepted role in clinical practice for more than 25 years, a growing body of evidence suggests that prehospital endotracheal intubation is not achieving its intended, overarching goal. In selected cases the intervention may actually be causing more harm than good (Wang & Yealy, 2006; Klemen & Grimec, 2006; Wang et al, 2004; Davis et al, 2003, 2005). The Cochrane Review (Lecky et al, 2008) has recently analyzed this issue to determine

whether emergency endotracheal intubation in seriously ill and injured patients improves their outcome in terms of survival and degree of disability. They conclude that:

“This review found no differences between endotracheal intubation and other airway securing strategies in reducing deaths after acute illness or injury; however, better studies are needed”.

This review also concludes that:

- clinicians need to establish safe airways and adequate ventilation for patients in emergency situations
- the skill level of the operator may be key in determining efficacy
- in pediatric and trauma patients the current evidence base provides no imperative to extend the practice of prehospital intubation to urban and short transit time systems.

Some important considerations have therefore emerged from what has been reported. Airway obstructions are common in numerous pathological emergency conditions, with consequent alterations in ventilation and oxygenation. The presence of important pathophysiological alterations (severe hypoxia, hypoperfusion and states of shock) can compromise the vital functions which, on the one hand, render the immediate execution of the intervention necessary and, on the other, can make airway management even more difficult (physiologically difficult airway).

In all probability, due to methodological and ethical issues, we must make do with studies based on low levels of evidence. Moreover, an analysis of the literature shows an extreme non-homogeneity between the quality of the studies, making it impossible to compare data. In particular, patients suffering from cranial trauma or cardiac arrest are often compared with those who are not and EMS systems are often very different (medical personnel or not, paramedics and technicians) (Herff et al, 2009).

2.3 Quality in prehospital airway management

Is successful prehospital endotracheal intubation are data itself enough to describe the quality of airway management? Unfortunately, the answer is no. It can never be stressed enough that it is not the mere positioning of the maneuver (in this case, the positioning of the tube in the trachea) which correlates with the outcome, but the total quality of the intervention on the scene and during transportation. It is evident that suboptimal airway management can create an increased risk in patients.

The so called “*inverse care law*” (Boylan & Cavanagh, 2008) states that, in the prehospital setting, the most critically ill patients are not always treated by those who are the most competent and expert. Operators and teams which are not competent and experienced enough do not guarantee a prehospital airway management in line with the established standards. This has obvious negative outcomes for the patients themselves, whether they are traumatized or not (Deakin et al., 2009; Warner et al, 2010, Timmermann et al, 2006; Fakhry et al, 2006).

For example, the indicators of insufficient quality in prehospital airway management are: a laryngoscopy and intubation performed without pharmacological help in reactive patients, repeated intubation attempts with resulting airway trauma, extended periods of

time on the scene due to patient instability, and the estimated control of the correct positioning of the tube in the trachea (Donald & Paterson 2008; Timmermann et al, 2007; Bacon et al, 2001).

Major complications in patients, like esophageal intubation or misplaced endotracheal tubes, range from as little as 0.3% to as much as 25% (Wirtz et al, 2007; Katz & Falk 2001). However, retrospective studies of endotracheal intubation are likely to have underestimated the true complication rate. These studies have often relied on the paramedic's own reports regarding success and complications and often reviewed emergency department records after the fact. Indubitably, in this case the problem is not endotracheal intubation but the quality of airway management itself.

An interesting study was conducted to evaluate the effects of rapid sequence intubation (RSI) on patients with severe traumatic brain injury (Davis et al, 2003). It concluded that prehospital endotracheal intubation in patients with severe traumatic brain injury was associated with an increase in mortality and a decrease in positive outcomes. The problem is the lack of attention paid to airway management complications and to post-intubation ventilation.

For instance:

- desaturation during the intubation attempt (especially in the case of very difficult airways)
- too much time on the scene
- post-intubation management (hyperventilation in head injured patients with increased risk of cerebral ischemia by hypocapnia)

How can we guarantee the best quality in prehospital airway management? First of all, we need to consider that airway patency is the best way of attaining our goals: oxygenation and ventilation. Far too often, the rescuers forget this and focus exclusively on the maneuver. Therefore, we need to consider that airway management (and more generally, prehospital care) is just a process and not a maneuver carried out by an individual rescuer. Teamwork is essential for successful airway management: the simultaneous intervention of expert rescuers assures the reduction of on-scene times, a better monitoring of vital signs and full cooperation with the principal operator ("intubator").

3. Prehospital airway management: an algorithm

Clear indications regarding treatment, what the priorities are and the availability of alternative plans allow the emergency team to intervene in a qualified, efficient fashion. On the basis of the best that has been published, it has been possible to create guidelines and a simple algorithm for prehospital airway management (Wang et al, 2005; Rich et al, 2004). The objective is to reduce errors during prehospital airway management, through rational, operative choices and in-depth patient evaluations. An algorithm must be simple to follow to allow operators to find a clear pathway in an emergency situation. This algorithm is the result of a collaboration between SIAARTI (the Italian Society of Anaesthesia, Analgesia, Reanimation, Intensive Care and emergency) and PAMIA (the Italian Association for Prehospital Airway Management).

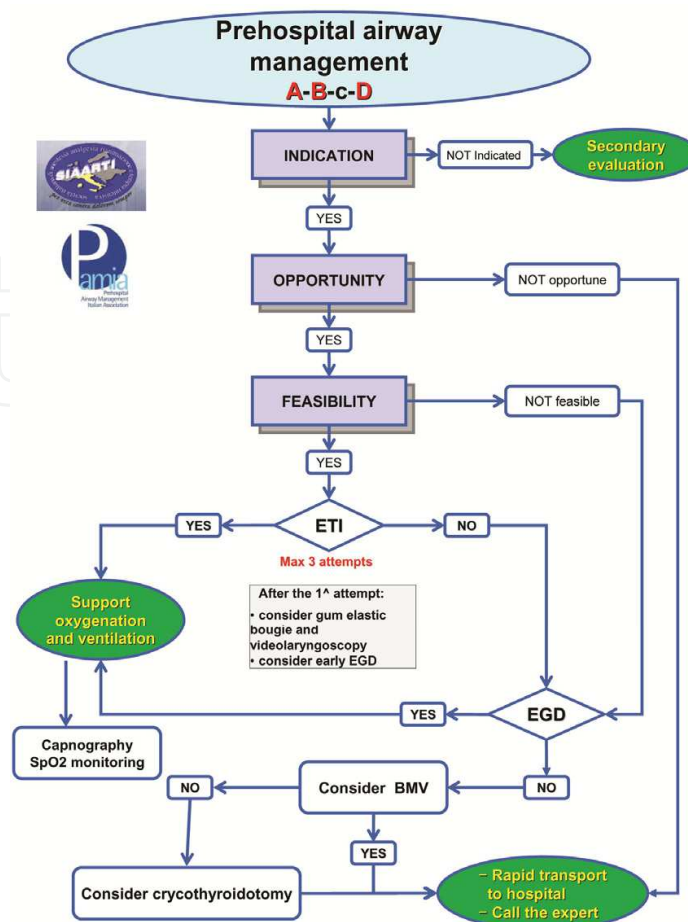


Fig. 1. The SIAARTI - PAMIA Italian Prehospital Airway Management algorithm.

The gold standard for airway management is tracheal intubation. The final decision to intubate the patient in the prehospital setting must always be the result of an extended evaluation. Although indication is only the first element, it is insufficient. In the algorithm, opportunity and feasibility have been added to the indication. In some cases the indication is clear. For example, an obstructed airway, severe hypoxemia with supplemental oxygen with mask and reservoir (high O₂ concentration), a GCS < 9 associated with hypoxia/hypoventilation or if the patient is suffering from cardiac arrest or is required to ensure immediate airway patency. There are some cases in which the indicated intubation can be carried out in the more protected environment of the hospital. The concept of opportunity requires a detailed example.

A traumatized patient suffers a head injury after a car accident and has a neurological problem (GCS < 9) on the scene. Almost all guidelines report that a patient with GCS < 9 must be intubated. We agree with these guidelines, but the question is: does the rescuer always intubate the patient on the scene? The answer is that it depends.

If the patient is able to ventilate spontaneously, has good blood oxygenation (SpO₂ ≥ 90) and intact gag reflexes and the Emergency Department (the right hospital) is nearby, it is inopportune to proceed with an endotracheal intubation. It is better to transfer the patient rapidly to the hospital where the emergency team can ensure an optimal airway management. This is especially true when the prehospital team does not have a lot of

experience when it comes to difficult airways. However, if the same traumatized patient is unable to ventilate sufficiently (low SpO₂) and/or has a high risk of pulmonary aspiration, it is opportune to assure the airway patency at the scene. The same is true if the right hospital is too far away.

When intubation is advisable, but not opportune, the algorithm indicates rapid transportation to the hospital and a call to the hospital emergency team. The aim is to guarantee continuity of care for the patient.

The third element in the decision to intubate regards its feasibility. Sometime an indicated and opportune prehospital endotracheal intubation is unfeasible. Unfeasible endotracheal intubation has been classified into three groups:

Operator/team dependent - Prehospital airway management is a team activity and an optimal performance requires the experience and competence of each and every member of the team. Generally speaking, all operators think that their personal experience is the main reason for an optimal airway management (Wang et al 2005, 2007). However, in many cases, if the operator has low levels of experience and carries out a small number of intubations per year, an endotracheal intubation might be unfeasible (Thomas et al, 2010). Airway skill maintenance is a real problem because many paramedics or physicians do not manage a sufficient number of cases to be able to manage complex situations. Airway management means teamwork and the team members must be properly trained. For this reason, it is important to perform simulations and to practice crisis resource management as often as possible. In general, paramedic and emergency physician training courses mainly emphasize airway management skills and techniques. Virtually no training is provided regarding the process of airway management; that is, how to assimilate and integrate airway assessment, management and procedural skills in response to changing conditions and non-technical skills.

Our algorithm provides a context for teaching this important concept.

Patient dependent - It is known that many anatomical features can prevent endotracheal intubation (for example, difficulty in opening the mouth and neck rigidity). Many traumatized patients can suffer from facial, or airway, traumas which render endotracheal intubation either difficult or impossible, even for the most competent and expert team. The ability to rapidly recognize the situations which can obstacle the coherent and correct carrying out of the maneuver allows us to avoid ulterior complications to the patient by using alternative plans.

Setting dependent -there are many difficulties (adverse lighting, the position of the patient, etc) which can lead to the unfeasibility of carrying out endotracheal intubation in the prehospital setting. If the patient is trapped in a car, for instance, a direct laryngoscopy is not feasible. If endotracheal intubation is unfeasible, the algorithm indicates the early use of extraglottic devices (EGDs)¹ to guarantee oxygenation and ventilation (Guyette et al, 2007; Kette et al., 2005; Frascone et al, 2008; Barata, 2008).

EGDs guarantee good oxygenation, adequate ventilation, and limit the risk of pulmonary aspiration. Several cases of EGDs being used on patients who are trapped in cars indicate

¹ In Italian Guidelines it is possible to read the definition of Extra-Glottic Device (EGD): literature indicates alternative devices as "supraglottic", while the GdS chose to group all ventilation devices that do not pass through the laryngeal aditus as "extraglottic" devices (Petrini et al, 2005).

that patients arrive in the Emergency Department with PaO₂ and PaCO₂ values within the limits of normality. The learning curve of EGDs is steeper if compared to the endotracheal intubation one.

If, at the end of an initial evaluation, endotracheal intubation is indicated, opportune and feasible, the operator and the team can proceed to intubate the patient. If the patient is not in cardiac arrest, the use of adjuvant drugs is indicated. Advanced airway management requires the selection of appropriate drugs for a particular clinical situation.

Correct drug selection:

- facilitates the laryngoscopy
- improves the likelihood of the quality and success of endotracheal intubation
- attenuates the physiologic response to intubation and reduces the risk of pulmonary aspiration and other intubation complications

However, drugs may cause side effects: for example, hypotension in patients with severe head injuries and hemorrhagic shock. Hypotension reduces cerebral perfusion and therefore increases the risk of ischemic cerebral damage.

When the team is preparing to intubate a patient, it must always bear in mind that the patient will suffer damage from hypoxia and not from the unsuccessful tracheal intubation. A simple laryngoscopy is considered to be "an attempt", even if the intubation is not actually performed. If endotracheal intubation is unsuccessful, we suggest to reassess the technique, the patient's position and the right dosage of drugs. The general rule is that the operator must not attempt to intubate the patient more than three times.

This is because if the tube cannot be positioned correctly after the second and third attempt, the rate of complications (hypoxia, regurgitation, airway trauma) increases dramatically and, in some cases, results in a "cannot ventilate cannot intubate (CVCI)" condition. A laryngeal manipulation technique can be useful; for example BURP - Backward, Upward, Right Pressure (Levitan et al, 2006).

The general rule is that three attempts should be made with alternative techniques and devices. After the first unsuccessful attempt, it is necessary consider an alternative plan.

In particular:

- the early use of EGDS: is, as mentioned previously, the best alternative in situations where it is too difficult to perform endotracheal intubation due to operator/team experience (unfeasible intubation)
- Gum elastic bougie: when the glottic view is limited (Cormack Lehane 2-e and 3) an introducer can be useful (Jabre et al., 2005). The gum elastic bougie technique is still used too little in the prehospital setting and therefore it is necessary to activate training courses to implement it.
- Videolaryngoscopy: in all probability, the future approach to airway management will be modified by the use of videolaryngoscopy in all settings. In the prehospital setting there are (Lim & Goh, 2009; Wayne & McDonnell, 2010) some situations which have demonstrated the usefulness of videolaryngoscopes, either as the instrument of first choice or as an alternative to a failed intubation attempt.

The possibility to train personnel in a different technique probably represents a favorable use of the videolaryngoscope. In any case, we should not forget the limitations of the videolaryngoscope, for example when you have a good view of the glottis but find it difficult to position the tube. This can be caused by the curvature of the blade, which can make it difficult to guide the tube inside the trachea (Bjoernsen & Parquette, 2008)

We should also briefly mention the use of the Sellick maneuver. This is recommended in reducing the risk of pulmonary aspiration during advanced airway management. Several recently published studies have cast doubt on the efficacy of the maneuver in reducing the risk of pulmonary aspiration, and also underline how it can worsen the visualization of the glottis and the positioning of a laryngeal mask (Ellis et al., 2007; Beavers et al. 2009).

A particularly delicate phase is represented by the control of the correct positioning of the tracheal tube. The literature reports various different ways of evaluating the correct position of the tracheal tube without encountering any particular problems, especially after a complicated, difficult laryngoscopy.

In this latter case it is not possible to visualize the passing of the tube through the vocal cords (an element which although useful, does not always guarantee that the tube is and, more importantly, remains correctly positioned). Moreover, auscultation and other indirect signs (expansion of the thorax) can be unreliable. For this reason, both instrumental and clinical evaluations are recommended.

In particular:

- capnography: it is evident that the capnographic curve (monitoring of end-tidal CO₂) allows us to be certain that the tracheal tube (and the EGD) has been positioned correctly and highlights an eventual accidental extubation (the disappearance of the capnographic curve). When it comes to the respiratory and cardiacirculatory state of the patient, capnographic monitoring is also recommended in the prehospital setting.
- oesophageal aspiration test (ODD) with self-expandable bulb or syringe: this is a very simple, inexpensive evaluation to perform and provides results which are extremely useful.

It will eventually be possible to identify tracheal rings or carina in the hospital with a fibrescope and, in some cases, identify the correct position of the tube by ultrasonography. The correct attachment of the tube is particularly important in the prehospital setting insofar as it is not uncommon for the tube to move (with the risk of positioning itself in the pharynx or in the esophagus) when the patient is being moved.

4. Prehospital intubation and drugs administration: rapid sequence intubation

If a patient is not experiencing a cardiac arrest and therefore present in one way or another, the tracheal intubation maneuver, as well as the positioning of a EGD, requires the administration of drugs.

The ideal conditions for advanced airway management are represented by the absence of the patient's muscle tone (it is facilitated by being able to open the mouth and, as a consequence, being able to visualize the glottides), the absence of induced responses (eg. vomit) and of endodynamic repercussions (tachycardia, hypertension and an increase in intracranial pressure).

Sedative-hypnotic drugs, analgesics, opiates, and other inductor medicines guarantee a significant efficacy, however, they are not without their dangerous side effects (which include the vasodilation effects of some sedatives-hypnotics which can cause severe hypotension in hypovolemic patients (especially in case of hemorrhagic shock).

The knowledge of the pharmacokinetic and pharmacodynamic properties of the drugs being used is essential to obtain the benefits and reduce undesirable side effects. It is not uncommon for a tracheal intubation attempt to be unsuccessful because not enough drugs were administered (often for fear of the side effects) or because onset times had not been respected. Alongside the choice of drug, it is also important to know how the drug is administered. A general diagram follows below.

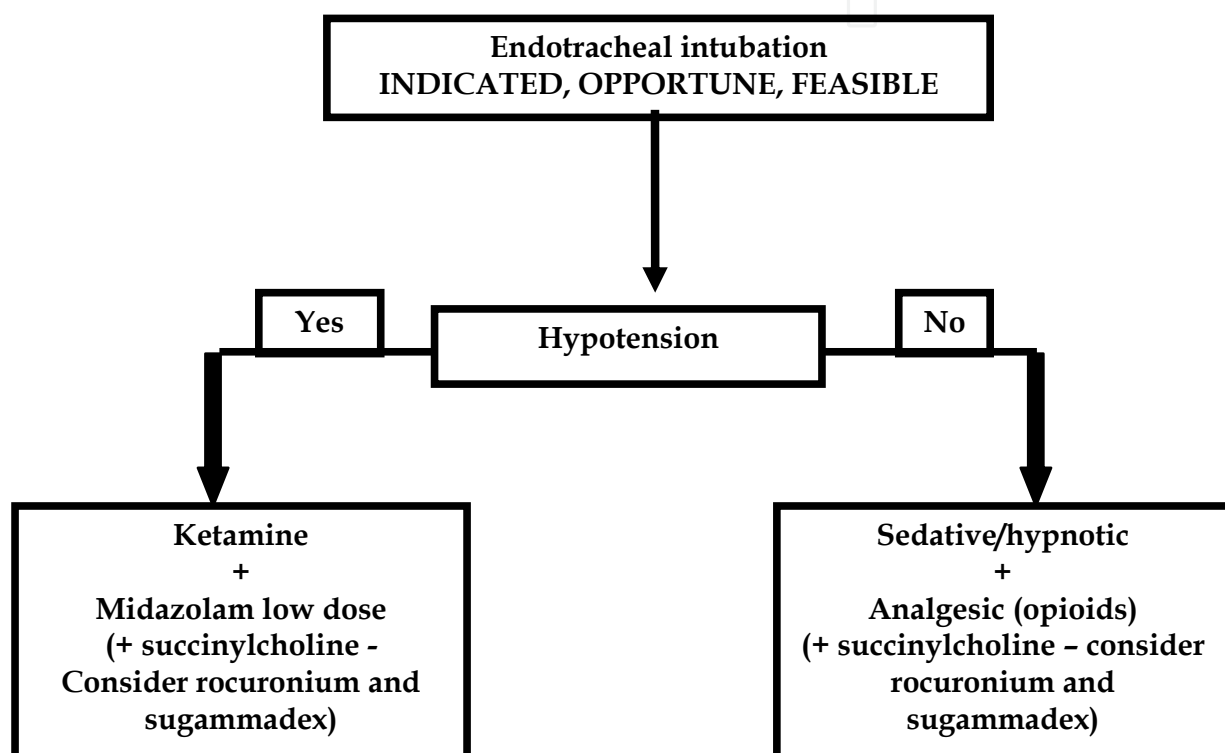


Fig. 2. The pharmacologic approach to endotracheal intubation in the prehospital setting.

An essential element in the choice of drug for tracheal intubation is represented by the patient's volemic state. It is recommended that hypovolemic patients use an inductor drug which guarantees hemodynamic stability and does not determine vasodilation or respiratory depression. Ketamine offers all of these advantages. Another excellent choice is etomidate, which has recently come under discussion for its corticosteroid synthesis suppression action.

Benzodiazepine (midazolam and opioid analgesics, in particular, fentanyl) are recommended for patients in a state of hemodynamic stability. An important element which needs to be considered is how to administer the drug.

The use of a combination of drugs is recommended increase their advantages, reducing their dosages and therefore their side effects. Moreover, when the patient's clinical conditions allow, (sufficient pulmonary exchange with $SpO_2 > 90$), a titrated drug administration is

indicated in order to obtain the desired result (sedation, muscular relaxation) with minimum dosages (less side effects).

Rapid Sequence Induction (RSI) was described over forty years ago (Stept & Safar, 1970). This technique was recommended in situations of anaesthesiological induction in patients with a full stomach in order to reduce the risk of regurgitation and successive pulmonary aspiration to a minimum. Over the years this technique has evolved into Rapid Sequence Intubation. RSI is defined as a series of steps, with the administration of sedative and paralytic agents, which facilitates rapid endotracheal intubation and minimize the complications. The paralytic agent of choice is succinylcholine. The recent availability of sugammadex might increase the use of rocuronium in the future.

An increasing body of evidence sustains the role played by sugammadex in the rapid reversal of neuromuscular blockade by rocuronium (at the maximum dosage, 16 mg/Kg.).

One of the advantages of administering rocuronium is that, if the patient is intubated, its considerable intubation dosage (0.6 - 1.2 mg/Kg) has a long-lasting effect and so facilitates mechanical ventilation. Succinylcholine has a short-lasting action and it is necessary to administer a long-acting neuromuscular blocking agent (i.e. vecuronium or rocuronium) after intubation. The paralytic agent can have significant side effects, the most important being apnea. If the operator/team is unable to ventilate and intubate the patient the consequences can be serious (CVCI with desaturation, bradycardia, cardiac arrest).

Some emergency medical services have introduced "*sedation facilitated intubation - SFI*": the rescuers use sedatives without any paralytic agents. The advantage of this is that it eliminates the risks associated with the use of muscle relaxants, but the side effect is that high dosages are required to obtain good, endotracheal intubation conditions.

A new technique, Rapid Sequence Airway (RSA) has recently been introduced (Braude & Richards, 2007) as an alternative to RSI. The pharmacological approach is the same as RSI: the operator can place an EGD immediately with the advantages of reducing the time necessary to obtain airway patency and thus reducing any side effects (i.e. hypoxia episodes during airway management). EGDs provide much more aspiration protection than many rescuers can believe.

The RSI steps are reported in the "9 Ps":

1. *Preparation* - The team verifies the availability of all that can be useful and mandatory for RSI. The SpO₂, ECG and blood pressure monitoring are activated. A "*sure*" venous access is obtained.
2. *Preoxygenation* - The patient is preoxygenated through an oxygen mask with a reservoir (if he/she is able to breath spontaneously) or a bag-mask system. High concentrations of O₂ are used to substitute the air in the lungs ("*denitrogenation*"). In this way the patient's oxygen reserves increase and desaturation during the apnea phase and the endotracheal intubation maneuver is less probable. If the patient is not breathing and is not ventilated, the desaturation progressively decreases, but if the lungs are rich in oxygen, the reduction is slow. The shape of the hemoglobin dissociation curve explains this. Serious problems can occur when the patient has a lung injury (contusion, laceration) or consolidation (pulmonary oedema, ARDS) which prevents good

pulmonary exchange and good blood saturation. In this case an immediate endotracheal intubation is necessary.

3. Pretreatment - the administration of drugs can be indicated to reduce the pathophysiological effects of laryngoscopy and intubation (for example, lidocaine 2 mg/Kg) or a defasciculating dose of non-depolarizing muscle relaxants in case of the use of succinylcholine (for example vecuronium 0,01 mg/Kg).
4. *Paralysis and sedation* - The administration of sedatives and muscle relaxants is certainly useful when carrying out the tracheal intubation maneuver. Suggested dosages are:
 - Midazolam 0.2 - 0.3 mg/Kg.
 - Fentanyl 1.5 - 2 mcg/Kg.
 - Ketamine 1 - 2 mg/Kg.
 - Etomidate 0.3 mg/Kg.

The administration of a sedative is followed by the administration of muscle relaxants. The suggested dosages are:

- Succinylcholine 1.5 mg/Kg.
 - Rocuronium 0.6 - 1.2 mg/Kg.
5. *Protection* - After the drugs have been administered, the patient is not ventilated to prevent the risk of gastric insufflation and regurgitation due to the relaxation of the upper esophageal sphincter. A team member applies the Sellick maneuver (until the tube's cuff insufflation and the verification of endotracheal tube position have been performed). With trauma patients, a team member carries out manual in-line stabilization (MILS) of the head to limit neck movements during the laryngoscopy and intubation.
 6. *Pass the tube* -the laringoscopy to introduction of the tube in trachea.
 7. *Positioning* - this is an extremely important phase. The operator verifies the correct position of the tube in the trachea using clinical and instrumental methods.
 8. *Postintubation management* - It is necessary to fix the tube firmly in the correct position because it can be displaced during transportation.
 9. *Plan "B"* - An emergency plan (for example, early EGD) must be always considered.

5. Prehospital ventilation: brief considerations

An important study by Davis et al, 2003 raises some problems. In particular, it reports that significant, inadvertent hyperventilation after an endotracheal intubation on the scene in patients with severe head injuries (low PaCO₂) was associated with a decrease in good outcomes (together with more time on the scene and desaturation during intubation attempts). We need to ensure the quality of prehospital emergency care; this means considering the "global" treatment of the patient. Airway patency is the way to reach our goals: oxygenation and optimal ventilation.

How can we improve early ventilation in the prehospital setting? Many traumatized patients arrive at the hospital suffering from hypocapnia as a result of hyperventilation. Hypocapnia causes cerebral blood flow reduction and consequent ischemia (secondary brain damage). For example, in 122 traumatized patients (Helm et al., 2002) optimal oxygenation was achieved in 85.2% and adequate ventilation (normocapnia, PaCO₂ 35 - 45

mmHg) in 42.6% of patients upon admission to hospital. Optimal oxygenation, as well as adequate ventilation, was achieved in 37.7% of the study population.

Hypoxemia ($\text{PaO}_2 < 60$ mmHg.) was observed in 2.5%, hypercapnia ($\text{PaCO}_2 > 45$ mmHg.) in 16.4% and hypocapnia ($\text{PaCO}_2 < 35$ mmHg.) in 40.9%. A high hypocapnia rate is not what we are looking for. An interesting conclusion of this study is that endotracheal intubation does not assure good ventilation *per se*. In all probability, the use of a capnography in the prehospital setting could guarantee better ventilation (Helm et al, 2003). It is necessary to consider the limitations of the capnography in unstable patients (the large difference between ETCO_2 and PaCO_2).

Setting ventilation at the tidal volume of 10 ml/Kg. is another important intervention in limiting inadvertent hyperventilation. The rescue team often uses manual ventilation, which has no controls on tidal volume and ventilatory frequency, and not portable ventilators.

We recommend the combined use of early, mechanical ventilation with controlled tidal volumes (*early* means immediately after the correct positioning of the verified tube) and continuous capnography (recommended for tube position control). Ideally, blood gas analysis could be helpful but its technical limitations reduce the use of this technique. The correct use of portable ventilators can reduce the incidence of the hemodynamic effects of positive pressure ventilation.

Positive intrathoracic pressure, which is determined by mechanical ventilation, causes a reduction in venous return and so reduces cardiac output and blood pressure (hypotension), especially in hypovolemic patients. The effect on blood pressure determined by positive pressure ventilation is important because it can cause severe secondary damage to patients (Pepe et al., 2003; Shafi & Gentilello 2005). The combination of hypotension and hypocapnia can be very dangerous for a traumatized brain.

6. Clinical cases

Here we report two clinical cases of difficult, prehospital intubation which consider the purposed algorithm as a pathway for the best patient treatment.

- a. The patient was a middle-age woman who was riding her bike. A car hit her at high speed. When the rescuers arrived, she was on the ground, comatose (GCS = 7; E1, V,2, M4), had vomit and noisy breathing; SpO_2 was 87% with high flow oxygen. The Trauma Center was far away: 50 minutes by ambulance. The physician evaluated the patient and decided to intubate because prehospital intubation was:
 - indicated: GCS < 9; airway partially obstructed; desaturation
 - opportune: the Trauma Center was far away
 - feasible: both the physician and the team were considered expert and there were no evident anatomic signs of difficulty

The team leader decided to apply the RSI. The heart rate was 82/ min. and blood pressure was 140/80 mmHg. The woman weighed 60 Kg. 12 mgs of Midazolam, 100 mcg of fentanyl. and 100 mg of succinylcholine were administered. The first intubation attempt was unsuccessful, and the patient desaturated rapidly during this attempt ($\text{SpO}_2 = 84\%$). The

physician (team leader) thought that the problem was an incorrect technique (his incorrect position and difficulties due to excessive manual in-line stabilization of the head).

He re-ventilated the patient with a bag-mask and positioned her correctly while a team member applied correct manual in-line stabilization of the head. The second intubation attempt failed too. The glottic visualisation was classified Cormack-Lehane (modified) 3-e (3 extreme).

On the third attempt the physician used an introducer but failed to position the tube inside the trachea. The patient was desaturated and a Laryngeal Tube was positioned with good ventilation and oxygenation by a portable ventilator. The patient arrived in the Emergency Room an hour later: the SpO₂ was 98%, and a blood gas analysis reported at PaO₂ = 99 mmHg. and PaCO₂ = 43 mmHg. She was intubated by the expert anesthesiologist with a laryngeal mask and fibroscope without any problem.

Comment: the physician probably did not evaluate the airway difficulty correctly, the patient remained on the scene too long and had severe complications (bad oxygenation). The choice of alternative device should have been the right choice to secure a valid oxygenation.

- b. A 42 yr. old lorry/truck driver (male, weight 80 Kg.) had an accident: he fell asleep and his lorry ran into another one. The cab was restricted and the driver trapped. When the rescuers arrived he was comatose (GCS = 3; E1, V1, M1) and gasping. The prehospital intubation was:
- indicated: GCS < 9 and gasping
 - opportune: the patient was entrapped
 - unfeasible: a direct laryngoscopy was not feasible.

The physician (an expert emergency helicopter physician) and the team considered using a videolaryngoscope and a plan B (early EGD). In this case, due to the patient's clinical conditions, the administration of sedatives and muscle relaxants was unnecessary. The physician verified his personal safety and, assisted by a team member, approached the patient from the front through the windshield. First, he applied a basic maneuver to open the airway and then inserted an Airtraq™ (Prodol, Spain) into the mouth. He obtained a good glottic visualization and the tube was inserted into the trachea. The videolaryngoscope permitted the control of the correct position of the tube (anterior to the arythenoids cartilage) and the physician ventilated the patient with a portable ventilator during the complex intervention by the fire department. When the patient was removed, the physician controlled the tube position and then transported him to the Trauma Center.

Comment: in this case, the high levels of experience and competence permitted the team to ensure a good quality of airway management in an extremely difficult situation, both because of the patient's condition and the setting.

7. Conclusions

In this chapter we described a linear, simple way to manage airway in emergency prehospital settings. The application of this algorithm to the real world requires a complete evaluation of material, personnel resources and a professional control by EMS directors.

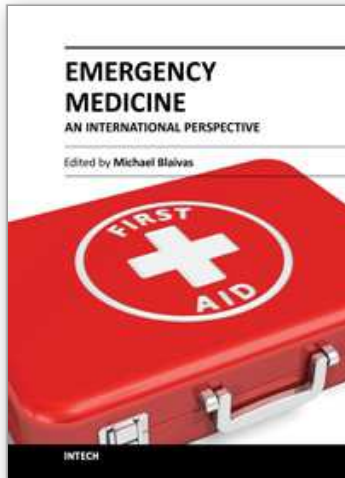
Prehospital airway management is a complicated field of emergency care but the data currently at our disposal regarding devices shows us that if emergency team personnel are adequately trained and follow a rational intervention procedure, high quality results will be obtained.

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