Airway Management in Trauma

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KEYWORDS

• Airway • Trauma • Airway management

KEY POINTS

- Airway management in trauma presents numerous unique challenges.
- A safe approach to airway management in trauma requires recognition of these anatomic and physiologic challenges.
- An approach to airway management for these complicated patients is presented based on an assessment of anatomic challenges and optimizing physiologic parameters.

INTRODUCTION

The "ABCs" of trauma resuscitation were born from the assumption that correcting hypoxemia and hypotension reduces morbidity and mortality. Definitive care for severely injured or polytrauma patients includes the ability to provide advanced airway management in a variety of settings: in the emergency department, 20% to 30% intubations are for trauma.[1,2] Airway management in the trauma patient presents numerous unique challenges beyond placement of an endotracheal tube (ETT), with outcomes dependent on the provider's ability to predict and anticipate difficulty and have a safe and executable plan.

DOES EARLY DEFINITIVE TRAUMA AIRWAY MANAGEMENT SAVE LIVES?

Despite significant advances in prehospital care, injury prevention, and the development of trauma systems, early mortality from trauma has essentially remained

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unchanged.[3] R. Adams Cowley, founder of Baltimore's Shock Trauma Institute, defined the "golden hour" as a window to arrest the physiologic consequences of severe injury by rapidly transporting trauma patients to definitive care.[4,5] The "stay and play" versus "scoop and run" approach to prehospital trauma care has been a topic of debate since the early 1980s.[6,7] Specific to airway management, there is evidence to support the argument that advanced airway management can be performed in the prehospital setting without delaying transfer to a trauma center.[8,9] More recent data suggest that when performed by skilled emergency medical services (EMS) providers, advanced airway management is associated with a significant decrease in mortality.[9,10] In the hospital setting, delayed intubation is associated with increased mortality in noncritically injured trauma patients.[11]

Conversely, there is a growing body of evidence that prehospital advanced airway management may increase mortality for trauma patients in some circumstances.[8,12–14] How does one reconcile this seemingly conflicting data? Is endotracheal intubation (ETI) for prehospital trauma patients harmful? The answer is, "it depends." The Eastern Association for the Surgery of Trauma (EAST) practice guidelines on ETI immediately following trauma acknowledged the conflicting prehospital data, stating the following:

"*No conclusion could be reached regarding prehospital intubation for patients with traumatic brain injury, with or without RSI* [rapid sequence intubation]*. Diversity of patient population, differing airway algorithms, various experience among emergency medical service personnel in ETI, and differing reporting make consensus difficult.*"[15]

It may be that the technical, procedure-focused management imperative of "getting the tube" is diverting attention away from the physiologic principles of oxygen delivery. Translated physiologically, the ABC priorities of trauma resuscitation are "stop the bleeding, maintain perfusion and oxygenate." Lifesaving oxygenation maneuvers may include a jaw thrust, temporary bag-mask ventilation (BMV), placement of a supraglottic airway device, or ETI. Advanced does not necessarily mean better.

TRAUMA AND THE DIFFICULT AIRWAY

A "difficult airway" is defined as difficulty with laryngoscopy and intubation, BMV, supraglottic device ventilation, and/or front of neck airway (FONA) access.[16,17] Anatomic markers are in general poor predictors of difficulty with airway management, with 90% of difficult intubations unanticipated, prompting debate about the value of trying to predict what is usually unpredictable.[18–21] The pathophysiology of trauma adds an additional layer of complexity and difficulty (**Table 1**).

The "physiologically difficult airway" is used to describe nonanatomic patient factors that can influence the outcome of airway management. Uncorrected hypoxemia, hypocapnia, and hypotension can have devastating consequences in the peri-intubation period. All trauma patients should have both anatomic and physiologic factors considered, planned for, and ideally corrected as part of their airway plan.[22]

In patients in whom both ETI and rescue oxygenation (bag-mask or supraglottic airway ventilation) are anticipated to be difficult, most existing airway algorithms recommend an "awake" intubation approach, in which the patient maintains spontaneous respiration throughout the procedure. There are a variety of reasons why awake intubation is uncommonly used for the trauma airway, and these are discussed later in this text.

Although the difficult airway is defined with reference to an experienced airway provider with an array of available recourses, other context-related challenges, including human factors, environment, clinician experience, and skill will invariably influence

Table 1
Predictors of difficult airway management in trauma

Difficult Airway	Trauma Related Difficulty	Approach
Difficult laryngoscopy and intubation		
Limited mouth opening/ jaw displacement	Collar/improper MILS Trismus	Open collar/ear-muff MILS
Inability to position	MILS	ELM/bougie/VL
Blood/vomitus	Facial injuries/full stomach, delayed gastric emptying	2 suctions/SALAD approach FONA
Penetrating or blunt neck trauma	Disrupted or distorted airway	Awake primary FIE; if not feasible RSI VL-assisted FIE
Difficult BVM		
Limited jaw thrust	Mandibular fractures	Early SGA use
Poor seal	Facial injuries with swelling, disruption	Early SGA use
Blood/vomitus	Facial injuries/full stomach, delayed gastric emptying	2 suctions/SALAD approach FONA
Penetrating or blunt neck trauma	Distorting subcutaneous emphysema, disrupted airway	Passive oxygen delivery/ minimize PPV
Difficult SGA use		
Blood/vomitus	Facial injuries/full stomach, delayed gastric emptying	2 suctions/SALAD approach FONA
Penetrating or blunt neck trauma	Distorted/disrupted airway	Direct visualization FIE/FONA, low tracheotomy
FONA		
Penetrating or blunt neck trauma	Distorted/disrupted airway CTM not accessible or injury at or below CTM	Low tracheotomy

Abbreviations: BVM, bag-valve-mask; CTM, cricothyroid membrane; ELM, external laryngeal manipulation; FIE, flexible intubating endoscope; FONA, front of neck airway; MILS, manual inline stabilization; PPV, partial-pressure ventilation; RSI, rapid sequence intubation; SALAD, suction-assisted laryngoscopy airway decontamination; SGA, supraglottic airway; VL, video laryngoscopy.

outcomes. Understanding when and why trauma patients may encounter difficulty in airway management can help guide the logistical and mental exercise of developing specific mitigating strategies and contingency planning. A call for help should always be viewed as a patient-focused measure, not a sign of provider weakness.

AIRWAY MANAGEMENT TRAUMA SCENARIOS

The Head-Injured Patient

Traumatic brain injury (TBI) is the most common cause of mortality in trauma patients. Airway management in this cohort of patients is often performed for airway protection. Given the relatively high incidence of peri-intubation desaturation, hypocapnea, and hypotension in emergency intubations, the benefit of ETI for airway protection to prevent aspiration must be weighed against the risk of the occurrence of physiologic adverse events known to increase morbidity and mortality in TBI patients.[23–26] If intubating for the purpose of airway protection, it is usually less time sensitive and should not be rushed. Every precaution should be taken to adequately preoxygenate and resuscitate first.

Apnea resulting from head injury requires immediate intervention. There are 3 mechanisms by which apnea may occur in TBI:

1. Severe or catastrophic brain injury
2. Impact brain apnea (IBA)
3. Loss of consciousness with resultant functional airway obstruction

Severe or catastrophic brain injury is usually nonsurvivable, and associated with early death. Predictions of outcome are usually not made until the patient has undergone a full trauma resuscitation, which often includes ETI. Contrastingly, IBA and functional airway obstruction may be correctable with simple airway opening maneuvers, with or without brief ventilation support. IBA from head trauma results in a primary respiratory arrest without significant parenchymal injury to the brain.[27] In contrast to patients with head injury with functional airway obstruction, patients with IBA do not respond to simple airway opening maneuvers alone, and may require brief ventilation support to prevent secondary hypoxic insult. With appropriate treatment, prognosis is generally good.

Head-injured patients with a decreased level of consciousness frequently receive prehospital advanced airway management.[10] In one series, 30% to 40% of patients are assessed as having partial or complete airway obstruction on EMS arrival.[10] A proportion of these patients will respond to basic maneuvers, and those who do not usually have more severe, less survivable injuries. This observation in part explains the comparatively poor survival rates for trauma patients who are intubated in the prehospital setting.

Management pearls for the patient with traumatic brain injury (TBI)

- Hypoxemia and hypotension during airway management significantly worsens outcomes in patients with TBI.
- Airway management for airway protection should proceed only after adequate measures have been taken to prevent intubation related physiologic disturbances.
- Postintubation hypocapnia is also associated with poor outcomes in patients with TBI and often the result of adrenaline induced overzealous postintubation ventilation.
- Postinjury apnea requiring ventilation support does not necessarily predict poor outcome.

Airway Management in Patients with Suspected Cervical Spine Injuries

Trauma resuscitations typically proceed under the assumption that the patient has an unstable cervical spine (c-spine) injury until proven otherwise. In the prehospital environment, trauma patients are often placed in a cervical spine collar and secured to a rigid backboard with blocks. Although a long-standing tradition in emergency medicine and trauma care, there is very limited published evidence to support the notion that cervical spine collars and immobilization prevent secondary spinal cord injury.[28,29] Although the incidence of c-spine injuries is relatively low (occurring in approximately 2% in the general trauma population and 6%–8% in patients with head and facial trauma), practitioners often operate with deep concern that intubation may cause secondary spinal cord injury, making it one of the most frequently encountered reasons for difficulty in trauma airway management.[30–33]

A frequently studied outcome is the amount of translational or angular movement of the cervical spine caused by airway manipulation. Although it appears that spinal movement occurs to a variable degree depending on the airway technique used, it is unclear whether or not this results in any important differences in clinical outcomes.[34] In cadaveric studies of unstable c-spine injuries, movement occurring with both direct laryngoscopy (DL) and indirect laryngoscopy do not significantly exceed the physiologic values observed with intact spines.[35,36] Despite the need to be cautious, even in patients with known cervical spine injuries, secondary neurologic deterioration is rare, with a reported incidence of 0.03%.[33,37–39]

Trauma patients with suspected spinal injury are typically fully supine, inhibiting the practitioner's ability to optimally position the patient for DL. Manual inline stabilization (MILS) worsens the view obtained with DL in up to 50% of cases.[40] Minimizing challenges with laryngoscopy and intubation mandates proper application of MILS, whereby the provider tasked with this role immobilizes the head and neck without immobilizing the mandible (**Fig. 1**). C-spine collars and improperly applied MILS will restrict mouth opening and tongue and mandibular displacement required for optimal laryngoscopy. Despite properly applied MILS, the provider should still expect a higher occurrence of a poor view with DL, longer intubation times, and more frequent failed intubation attempts.[40] This scenario is often easily managed by applying external laryngeal manipulation or use of a bougie.

Another theoretic concern is that application of MILS results in the need for an increased applied force during laryngoscopy, which paradoxically may lead to more movement during intubation than occurs without MILS.[40,41] Recognizing our inability to correct the fundamental geometric challenge of DL, the provider may opt to use a "look-around-the-corner" indirect device, such as a video laryngoscope with a hyperangulated blade. The 3 classes of video laryngoscopes are described in **Box 1**.[42]

Box 1
Classes of video laryngoscopes

1. Macintosh video laryngoscopy (VL; also known as standard geometry blade) for example, C-MAC (Mac Blade; Karl Storz, Tuttlingen, Germany), McGrath Mac (Mac blade; Medtronic, Minneapolis, MN), GlideScope Titanium Mac (GlideScope, Verathon, WA), Venner APA (Mac blade; Venner Medical, Singapore, Republic of Singapore).
2. Hyperangulated VL (also known as indirect VL), for example, C-MAC (D-Blade), McGrath Mac (X blade) standard GlideScope, KingVision (nonchanneled blade; Ambu, Ballerup, Denmark).
3. Channeled blade VL, for example, King Vision, Pentax AWS (Pentax, Tokyo, Japan), Airtraq (Teleflex Medical, Wayne, PA).

Data from Kovacs G, Law JA. Lights camera action: redirecting videolaryngoscopy. EMCrit. 2016. Available at: https://emcrit.org/blogpost/redirecting-videolaryngoscopy/. Accessed February 25, 2017.

It would seem intuitive that because indirect hyperangulated video laryngoscopy (VL) consistently provides an improved glottic view and that c-spine immobilization consistently impairs the glottic view with DL, that VL is the better choice for trauma patients.[43–45] However, having a good view with VL does not mean that easy ETI will follow.[46] When using a hyperangulated video laryngoscope, a deliberate restricted view may be desired to facilitate the often seemingly frustrating paradox of having a great view of the glottis but not being able to deliver the ETT.[42,46,47]

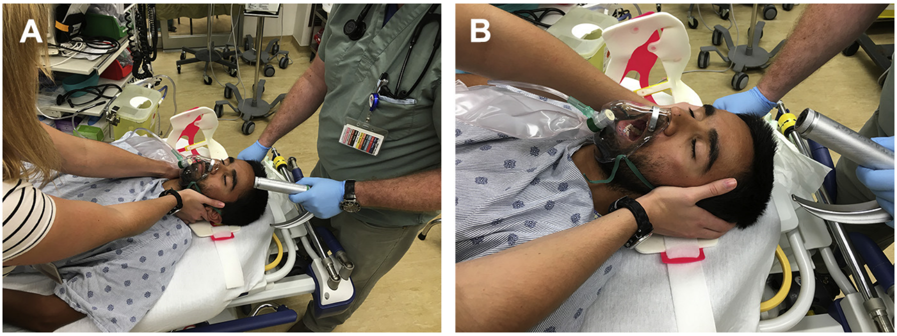

Fig. 1. (*A*) MILS applied incorrectly limiting mandibular range of motion (ROM). (*B*) MILS applied correctly with hands over the ears (ear-muff approach) not limiting mandibular ROM.

Literature comparing intubation devices in c-spine immobilized patients has yielded inconsistent findings, and no consensus as to the optimal approach.[38,44,45,48,49] A recent meta-analysis by Suppan and colleagues[45] reported more failed intubations for DL compared with several alternative intubating devices in patients with c-spine immobilization. Although the investigators acknowledge the weaknesses of available literature, they note there was no statistically significant difference in first-attempt success between the more commonly used VL devices (GlideScope, C-MAC) and DL.[45] It is less likely that there is a "the right device" for the unstable c-spine and more important is the right experienced practitioner, using a device with which he or she is the most comfortable.[50,51]

Airway management in the patient with a possible c-spine injury must strike a balance between minimizing movement and the need to quickly and successfully intubate on first attempt, thereby minimizing the harm of hypoxemia that may be associated with multiple attempts at intubation.[52] It seems reasonable to consider that if the patient's spinal cord has survived the massive forces of the crash, as well as repositioning during extrication and immobilization, that the chances that movement occurring during *controlled* airway management will result in cord injury is extremely low. As suggested by Aprahamian and colleagues,[33,53] the primary benefit of a rigid cervical collar is to serve as a reminder about the potential existence of an unstable c-spine injury.

Management pearls for patients with unstable cervical spine injuries

- Imaging should not delay airway management and assume all trauma patients have unstable cervical spines.
- The provider should optimally use the intubation device he or she is most experienced with.
- Be prepared for a poor view with direct laryngoscopy (DL) and always have a bougie ready for use.
- Rigid cervical collars must be opened or removed and replaced by properly applied manual inline stabilization (MILS).
- Properly applied MILS should avoid immobilization of the mandible.
- If using a hyperangulated video laryngoscope, a deliberate restricted glottic view may facilitate difficult ETT advancement.

The Contaminated Airway

The presence of airway contamination with either blood or vomitus has been shown to decrease the rate of first-attempt intubation success, regardless of the device used.[54] Blood and vomit in the airway can lead to early and late complications related to difficult airway management and/or aspiration. The bloody airway is not uncommon in trauma patients with injuries to the face and/or neck and may range in severity from scant bleeding, which is easily managed, to significant hemorrhage. The combination of altered levels of consciousness, diminished protective airway reflexes, delayed gastric emptying, and full stomachs place trauma patients at high risk of vomiting and aspiration during airway management. Management of contaminated airway must begin with the expectation that the degree of blood, vomit, and secretions appreciated externally represents only a fraction of what may be encountered on initiation of an RSI. As such, providers must ensure that adequate suction is available (at least 2 large rigid suction catheters). Consideration must be given to positioning, placing the patient in reverse Trendelenburg or, if safe to do so, seated upright or even leaning forward to allow drainage of blood and secretions. For c-spine immobilized patients, suction must be immediately within reach, and restraints securing the patient to the bed should be avoided. During the preoxygenation phase, positive-pressure ventilation (PPV) should be used only if necessary balanced against the patient's oxygenation status, as ventilatory pressures of 20 cm H2O or more are likely to ventilate the stomach, increasing the risk of regurgitation and aspiration.

When blood or vomitus is overwhelming suction capabilities, the provider may place either one rigid suction or an ETT in the upper esophagus to divert the offending contaminants. The ETT or rigid suction may then be stabilized to the left of the laryngoscope and the second suction used during laryngoscopy in search of the epiglottis (Fig. 2). Often the epiglottis may be "lifted" (more easily accomplished in a reverse Trendelenburg) out of the contaminant during laryngoscopy, providing an anatomic reference for placing a bougie.

Most of the literature comparing DL with VL in the bloody or vomitus-filled airway is simulation-based, and concern exists about the vulnerability of VL camera lens in the contaminated airway.[55,56] Recently, Sakles and colleagues[54] retrospectively reviewed

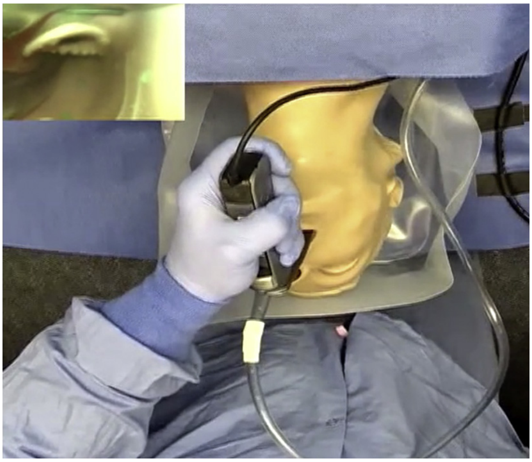

Fig. 2. Suction in upper esophagus stabilized to left of laryngoscope (SALAD approach). (*Courtesy of* Ruben Strayer, MD.)

more than 4600 intubations and demonstrated that, although airway contamination was associated with a decreased first-attempt success rate, this was irrespective of the choice of GlideScope or DL as the first-attempt device used. The use of DL or Macintosh VL, in which a direct approach can be used if the camera is obscured with the aid of a bougie, may be preferred approaches.

Although not studied in a clinical setting, the Ducanto suction-assisted laryngoscopy airway decontamination (SALAD) approach has gained acceptance as a method to manage the soiled airway.[57,58] In the uncommon circumstance in which blood or vomit is overwhelming these management strategies, intubation is not possible and the patient is critically desaturating, rescue oxygenation with a BVM (bag-valve-mask) or SGA (supraglottic airway) is unlikely to work and an FONA approach is indicated.

Ducanto suction-assisted laryngoscopy airway decontamination approach to managing massive airway contamination

- Use rigid large-bore suction to initially decontaminate
- Perform laryngoscopy keeping blade superior against tongue away from fluid
- Advance suction tip into upper esophagus then wedge in place to left of the laryngoscope
- Use second suction as needed
- Rotate laryngoscope blade 30 degrees to the left to open blade channel
- Place endotracheal tube (ETT), inflate the cuff

Management pearls for the patient with the contaminated airway

- Have at least 2 large-bore rigid suction catheters.
- Consider alternative options for hemorrhage control (sutures, packing, epistaxis kit).
- Minimize positive-pressure ventilation (PPV) and use a monometer for provider feedback when mask ventilation is indicated.
- Look for epiglottis as an important landmark for glottis and have a bougie prepared for use with DL.
- If a VL is considered the best option, Macintosh VL may be the preferred device, as it may be used directly if contamination obstructs camera.
- Consider esophageal ETT diversion connected to suction.
- Suction-assisted laryngoscopy airway decontamination (SALAD) approach.
- If intubation fails and patient is desaturating, front of neck airway (FONA) rescue oxygenation approach is indicated.

The Uncooperative or Agitated Patient

Uncooperative, violent, or agitated patients can encumber adequate assessment, leading to missed injuries and inadequate resuscitation. Agitation can be multifactorial and may be the result of head injury, hypoperfusion, hypoxemia, or intoxication. It may not be clear why a patient is agitated and providers must determine if the patient is agitated *AND* injured or agitated *BECAUSE* the patient is injured.

The EAST guidelines recommend that aggressive behavior refractory to initial pharmacologic intervention is a discretionary indication for intubation; specifically that if a patient's level of agitation prevents assessment and resuscitation, intubation and sedation should follow.[15] Sise and colleagues[59] reviewed 1078 trauma patients intubated for discretionary indications (eg, agitation, alcohol intoxication) and found that 62% of patients, once investigated, had a significant head injury. Importantly, there was no significant difference in complications associated with acute airway management in patients intubated for discretionary indications, as compared with those intubated for higher acuity reasons.[59]

In severely agitated patients, RSI is at times undertaken before optimal hemodynamic resuscitation and preoxygenation has been achieved. Patients rendered apneic as part of an RSI without adequate preoxygenation are at high risk of desaturation. The use of ketamine to facilitate cooperation and allow interventions including preoxygenation has been described as "delayed-sequence intubation" by Weingart and colleagues.[60] If given slowly, a dissociative intravenous dose of 1 to 1.5 mg/kg poses little risk of respiratory depression. However, the use of any sedative, particularly in the presence of other intoxicating ingestions, may inhibit airway reflexes. Concerns that ketamine may raise intracranial pressure and worsen outcomes in TBI is not supported by evidence.[61,62]

Management pearls in the agitated trauma patient

- Agitation may be a symptom of traumatic pathology.
- Agitated patients may require facilitated cooperation to ensure adequate preoxygenation.
- Ketamine is an appropriate agent to facilitate cooperation in agitated patients in preparation for airway management.
- Always be prepared to provide definitive airway intervention before administering sedation.

Maxillofacial Injuries

Maxillofacial fractures may present dramatically and affect airway management in one of several ways.[63] Posterior displacement from fractured maxillofacial segments may cause soft tissue collapse and occlude the airway, which may be worsened by the presence of c-spine collar.[64,65] Bleeding may be significant and cause airway management challenges, as previously discussed. In the supine position, the pooling of blood in the oropharynx may stimulate a gag response or vomiting, which in turn may worsen bleeding. Although patients with mandibular fractures in 2 or more locations may be easier to intubate due to increased mobility of the mandible and attached soft tissues, associated condylar fractures may cause a mechanical obstruction limiting mouth opening, making laryngoscopy and intubation difficult.[64,66] Maxillofacial fractures may also cause trismus that may resolve with the neuromuscular blockade; however, differentiating this from a mechanical obstruction before intubation is required and is often difficult.

Airway management begins with careful consideration to patient positioning. Awake, neurologically intact patients without neck pain should be allowed to position themselves however they are most comfortable to control tissue obstruction and allow drainage of blood and secretions. They may be given a rigid suction catheter to use themselves, which is more often tolerated, effective, and less likely to stimulate a gag and resultant vomiting. Adherence to protocols requiring rigid spinal immobilization and supine positioning may result in catastrophe.

The provider should presume that preoxygenation in patients with facial trauma may be difficult, and that reoxygenation with mask ventilation during RSI if the first attempt is unsuccessful may be difficult or impossible. Distortion of facial structures may make obtaining a seal with a BVM device difficult and patients may poorly tolerate PPV, as disruption of tissues may result in worsening bleeding and in cases of associated lower airway trauma, significant subcutaneous emphysema. Practitioners must proceed with the assumption that structural collapse of the airway may occur during an RSI.

The choice of approach is based on the patient's ability to maintain a patent airway and their oxygenation status. For a "have no time" scenario (obstructing and hypoxemic), the primary approach may require a FONA, facilitated by a dissociative ketamine dosing. Alternatively, a "double set-up" may be used: RSI with a single attempt at oral intubation followed immediately by FONA rescue if needed (Fig. 3).

If the patient is maintaining adequate oxygenation, the clinician should proceed with a focused physical examination to assess the specific pattern of facial injury and plan accordingly. For example, swelling and tenderness at the temporomandibular joints suggests the presence of condylar factures and the possibility of mechanical trismus. Because anticipated difficulty in patients with facial trauma may involve challenges with intubation, mask ventilation, and possibly supraglottic airway rescue, preservation of spontaneous respiration during attempts to secure the airway should be considered. These patients may be best served when feasible by an "awake" approach with a laryngoscope or flexible intubating endoscope (FIE) or in selected cases a primary FONA.

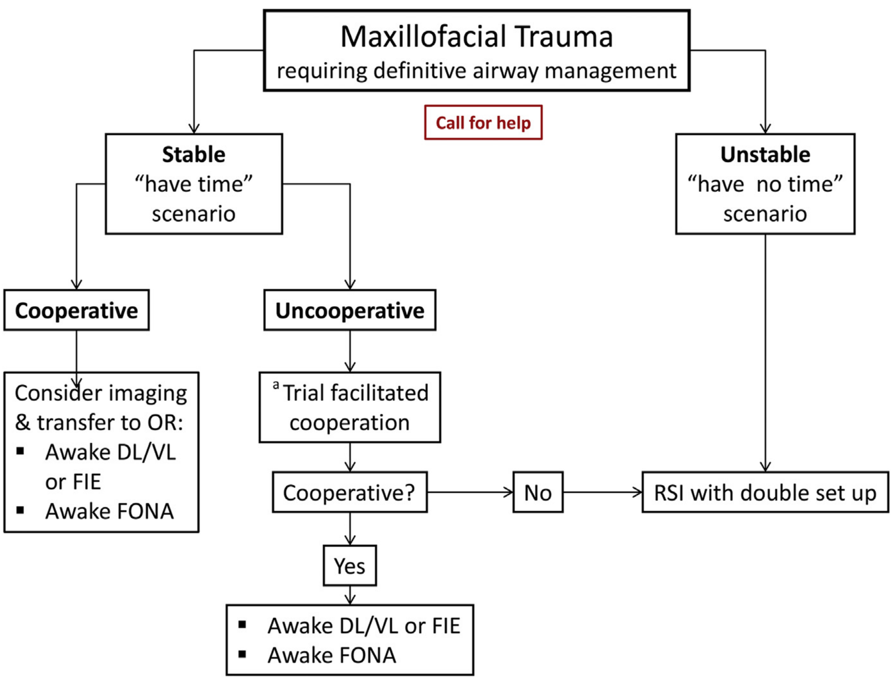

Fig. 3. Approach to maxillofacial trauma. OR, operating room. [a] Facilitated cooperation using ketamine. (*Adapted from* Mercer SJ, Jones CP, Bridge M, et al. Systematic review of the anaesthetic management of non-iatrogenic acute adult airway trauma. Br J Anaesth 2016;117(Suppl 1):i55; with permission.)

Management pearls for the patient with facial injuries

- These patients require careful assessment of damaged anatomy recognizing the unique airway complications associated with facial fractures.
- Both laryngoscopy and mask ventilation may be challenging and a double set-up should be prepared for when rapid sequence intubation (RSI) is the chosen approach.
- An awake approach, although not always practical, should be considered.
- Management of aggressive bleeding should be anticipated.
- Allow patients to assume a position of comfort when safe to do so.

The Traumatized Airway

Airway management for the patient with a primary injury to the larynx or trachea is a high-stakes scenario, in which the loss of a stable airway can happen rapidly and with little warning. Suspicion of a traumatized airway should initiate a call for help to an experienced colleague.

Primary airway trauma is relatively uncommon in the civilian urban setting, with a reported incidence of less than 1% (0.4% for blunt and 4.5% for penetrating injuries).[67] Accordingly, practitioners have infrequent or limited experience in managing these patients and existing management guidelines for care of these patients are mostly based on expert opinion.[68]

Clinical findings suggestive of significant laryngotracheal airway injury include dysphagia, hoarseness, stridor, bleeding in the upper airway, subcutaneous emphysema, expanding hematoma, or in open penetrating injuries, obvious disruption of the larynx or trachea. If airway injury is suspected, aggressive PPV should be avoided. PPV in the setting of airway disruption can create or worsen pneumothorax, pneumomediastinum, or subcutaneous emphysema. Massive subcutaneous emphysema can distort airway anatomy, further complicating management. A potentially catastrophic complication is the conversion of a partial tracheal transection into a complete transection with the force of blindly passing an ETT or a bougie, particularly if relying on distal “hold-up” to confirm placement.[68,69]

For patients with known or suspected airway injury, the safest way to facilitate ETI is placement of the ETT under direct visualization, ideally from the oropharynx to the carina using an FIE.[68,70] Mercer and colleagues[68] described an approach to managing patients with suspected laryngotracheal injury (**Fig. 4**). In the “have time” scenario in the patient who is oxygenating with minimal assistance, awake, and cooperative, the airway can be approached either from above after adequate topicalization, using a FIE, or infraglottically with a FONA approach (most commonly an awake tracheostomy) depending on the location of the injury.

Careful titration of ketamine is often desirable to improve comfort and cooperation while maintaining airway reflexes. Use of an FIE allows both a diagnostic and therapeutic advantage: visualizing the specific pattern of injury, and facilitating careful ETT placement, while avoiding conversion to a complete transection. If an area of partial injury is identified, the FIE can be advanced distally and used as a guide to ensure safe advancement of the ETT beyond the site of injury.

In a “have no time” situation with a deteriorating patient in whom an RSI is considered the only viable option, a double set-up is mandatory, recognizing that the level of airway breach will influence whether FONA can occur through the cricothyroid membrane or if a tracheostomy is required. One option to improve visual navigation past the airway injury is to use a VL-assisted flexible endoscopic intubation.[71] In this

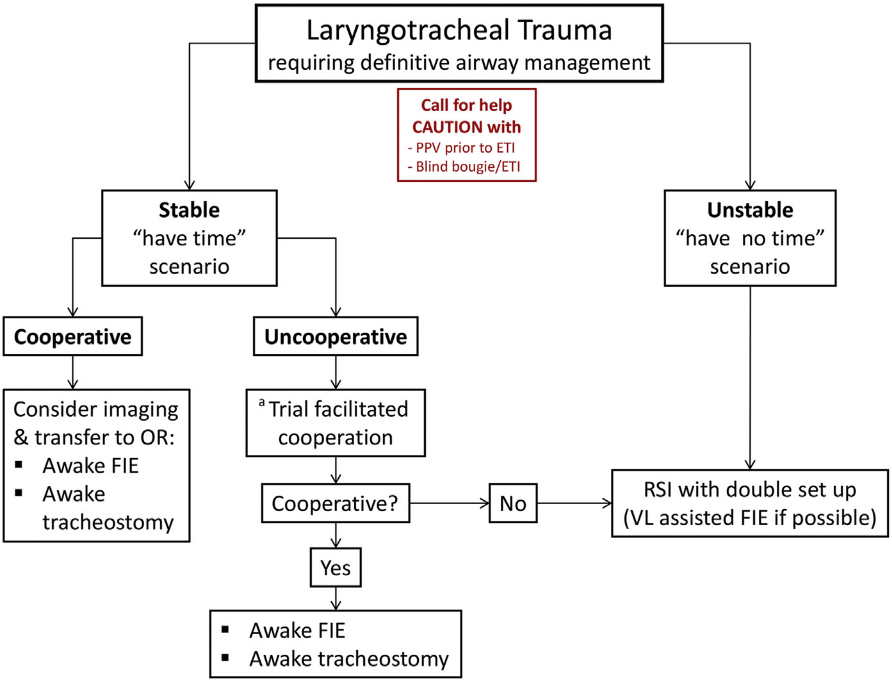

Fig. 4. Approach to laryngotracheal trauma. [a] Facilitated cooperation using ketamine. (*Adapted from* Mercer SJ, Jones CP, Bridge M, et al. Systematic review of the anaesthetic management of non-iatrogenic acute adult airway trauma. Br J Anaesth 2016;117(Suppl 1):i56; with permission.)

scenario, an RSI is initiated in the usual fashion and a VL is used to control soft tissues and obtain a view of the glottic inlet. A flexible intubating endoscope is then advanced through the vocal cords with the visual aid of VL distally to the carina facilitating inspection of the airway, and the ETT is advanced over the FIE into position.

Management pearls for the patient with a primary airway injury

- Decompensation in the patient with a traumatized airway may be rapid and catastrophic.
- PPV should be avoided if possible.
- An awake approach with appropriate topicalization is the preferred approach.
- If an RSI is chosen, a double set-up with a FONA plan for accessing the trachea based on the level of the airway breach.
- ETT placement should ideally be performed with visualization of the airway using a flexible intubating endoscope (FIE).
- Advanced techniques using FIE either primarily in an awake patient or assisted by VL when an RSI is chosen are recommended when resources and skill are available.

THE AWAKE INTUBATION

A successful awake intubation is dependent on careful patient selection, and, in particular, identifying anatomic, pathologic, or physiologic features that would make RSI problematic. There are several specific patient populations, including the burn patient and the patient with penetrating neck injuries, in whom an awake intubation may be the approach of choice, as a strategy to mitigate both predicted difficulty and anticipated dynamic changes in airway anatomy and physiology.

The awake intubation is a "have time" approach, involving placement of an ETT following adequate topicalization in a patient who is able to maintain spontaneous respirations. It is not device-specific and can be performed using DL, VL, or an FIE. Success with awake intubation is dependent on meticulous airway topicalization, and in general requires an awake and cooperative patient.[72,73] The use of sedation is not routine, and has been associated with increased awake intubation failures.[74] Specifically, sedation should never be used in place of adequate airway topicalization. A difficult airway paradox exists here: patients identified as difficult are selected to undergo a technically more challenging awake approach, a procedure that is performed infrequently by most emergency physicians. There is no simple answer to this resource, skill availability dilemma. It is our opinion that physicians who are responsible for acute airway management should acquire and maintain the skills required for awake intubation, as it can be a lifesaving approach in a specific subset of dynamic airway situations.

RAPID SEQUENCE INTUBATION

RSI involves the rapid administration of an induction agent and a neuromuscular blocking agent in quick succession to facilitate ETT placement in a patient who is presumed to have a full stomach. RSI is the most common approach for airway management in trauma.[75,76] Oxygenation with or without ventilation during the procedure (referred to by some as a "modified" RSI) is considered standard by most acute care practitioners.[77–79] Historically, the application of cricoid pressure (CP) to prevent passive aspiration has been considered an essential component of an RSI. However, its routine use remains controversial, with some evidence suggesting it may make various aspects of airway management more challenging. If cricoid pressure is being applied and the practitioner experiences difficulty with laryngoscopy, intubation, or ventilation, CP should be immediately discontinued.[80,81]

Hemodynamic instability and hypoxemia must be aggressively managed before attempting RSI.[22,23] The "rapid" part of an RSI refers to the delivery of the induction drug and neuromuscular blocking agent, and is not meant to imply a hurried or rushed process. RSI in underresuscitated patients may result in unintended poor outcomes, including critical hypoxemia and circulatory collapse.[82,83] The term "resuscitative sequence intubation" has been suggested as a more representative term used to describe the preparation and optimization of the patient's physiologic status before definitive airway management.[84]

Preparation

Numerous preparatory airway acronyms and checklists have been proposed to reduce errors and adverse events associated with RSI.[85,86] Although evidence of outcome benefit may be lacking, based on an increased understanding of the role of human factors in contributing to adverse airway outcomes, it seems a reasonable recommendation that an airway checklist be used in the preparation phase of trauma airway management.[87–91] In general, checklists should be simple, use terminology that is clearly understood by the entire team, and can be performed rapidly (**Fig. 5**).

Optimizing Hemodynamics

Hemodynamic instability in trauma is most commonly caused by hypovolemia due to hemorrhage. Intravascular depletion shifts the gradient between right atrial pressure

Airway Checklist

Before Intubation → Intubation → After Intubation

Team Ready?

- ☐ EP aware/Experienced airway staff present
- ☐ Do we need additional help?
- ☐ Assign roles: Lead/MILS/BVM/Drugs/ETI

Patient Ready?

- ☐ Monitor (Pulse ox, ECG, BP, EtCO2)
- ☐ Positioning
  - ☐ Ear to Sternal Notch
  - ☐ Reverse Trendelenberg 30°
  - ☐ Ramp if obese
- ☐ Dual PreOxygenation (Both)
  - ☐ Nasal Cannula @ 15+LPM AND
  - ☐ NRBM @ 15 -> flush LPM OR If Sats <96%
  - ☐ BVM/PEEP 5–10 cm (passive) OR
  - ☐ NIV
- ☐ Fluid Bolus
- ☐ Pressor support (consider if SI >.8)

Equipment Ready?

- ☐ BVM with PEEP/Pressure manometer
- ☐ DL/Mac VL ETT stylet 30–40° + Bougie
- ☐ HA-VL ETT stylet 60–70°
- ☐ Suction (1–2)
- ☐ SGA sized
- ☐ Bougie cric equip available
- ☐ Ventilator/RT support

Airway Assessment & Plan

- ☐ Estimated Level of Difficulty Laryngoscopy/BMV/SGA/Surgical (Circle) Low, Moderate, High, Very High
- ☐ Considered Dangerous Physiology Low BP/low Sat/low pH/RV strain
- ☐ RSI vs. "Awake" approach
- ☐ Medications
  - ☐ RSI Induction/NMBA doses
  - ☐ Awake lido 4% Ez spray/5% oint
  - ☐ Ketamine facilitated coop .5–1.5 mg/kg
  - ☐ Post intubation sedation
- ☐ Plan A - Primary – DL, Mac VL+ Bougie or HA-VL
- ☐ Plan B - ReOx b/w ETI-> OPA/2-hand BVM
- ☐ Plan C – Alternative ETI approach
- ☐ Plan D - Rescue Ox-> SGA/bougie cric

Intubation

- ☐ Time Out – "All ready?" "Give drugs"
- ☐ Post RSI meds 45 sec count down
- ☐ Passive BVM+HFNO/vent prn
- ☐ Prob solve ETT advancement
  -ETT turn left over bougie
  -Stylet with VL ETT turn right
- ☐ EtCO2 (Waveform)

Post-Intubation

- ☐ Continuous Waveform Capnography
- ☐ Cycle pressures q3min
- ☐ Sedation/analgesia orders
- ☐ Consider ongoing NMBA
- ☐ OG Tube Placement prn
- ☐ CXR
- ☐ Restraints Prn
- ☐ Review ventilator settings

☐ **Debrief**

1) What went well? ____________ ☐ See Back

*2) What could be strengthened & how? ____________ ☐ See Back

☐ **Difficulty Rating** (Post Intubation)
(Circle) Low, Moderate, *High, *Very High

*For "High/Very High" Difficulty Ratings:

- ☐ Directly communicate to CC staff
- ☐ Document on chart
- • What made the Airway Difficult?____ ☐ See Back

Fig. 5. Intubation checklist example. BP, blood pressure; BVM: bag-valve mask; CXR, chest radiograph; DL: direct laryngoscope; ETI: endotracheal intubation; ETT: endotracheal tube; HFNO: high flow nasal oxygen; LPM: leters per minute; MILS: manual in-line stabilization; NIV: non-invasive ventilation; NMBA: neuromuscular blocking agent; NRBM: non-rebreather mask; OG: orogastric; pulse ox, pulse oximetry. ReOx: reoxygenation; SGA: supraglottic airway; SI: shock index (SBP/HR); VL: video laryngoscope. (*From* SaferAirway.org Toolkit (Emergency Medicine Associates, Germantown, Maryland); with permission.)

and mean systemic pressure, reducing preload and subsequently mean arterial pressure. The transition to PPV, either through a closed system BVM with an attached with positive end-expiratory pressure (PEEP) valve or with mechanical ventilation once intubated, abruptly increases the intrathoracic pressure, further shifting this gradient.

Postintubation hypotension is defined as a systolic blood pressure (SBP) <90 mm Hg or a mean arterial pressure <65 mm Hg within 30 minutes of intubation.[92] Inadequate resuscitation of hemorrhagic shock, transition to PPV, loss of sympathetic drive associated with general anesthesia, and the hemodynamic effect of many induction drugs are all contributing factors. The incidence of post intubation hypotension is high in patients requiring emergency airway management (23%–46%), which is important because even transient drops in blood pressure are associated with adverse outcomes in trauma patients.[23,92–94] Patients with a shock index (defined as heart rate divided by SBP) of greater than 0.8 are at particular risk of developing significant hypotension in the postintubation period.[82,95,96] The combination of hypoxemia and hypotension is additive, with an adjusted odds of death double that of the increased mortality associated with either event alone.[23,97,98]

Early use of blood products is recommended when the etiology of shock in trauma is believed to be from hemorrhage. Vasopressors have traditionally been avoided in trauma based on concerns that they may worsen bleeding. During the peri-intubation phase, early aggressive use of blood products and hemorrhage control measures (splinting, pelvic binding) should remain the mainstay of resuscitation efforts. Careful use of vasopressors should be strongly considered in at-risk head-injured patients to prevent or manage postintubation hypotension. Sustained vasopressor use by infusion beyond the immediate peri-intubation period may be required to mitigate the effects of PPV, postparalysis sedation, and ongoing losses unresponsive to fluid and blood product replacement.

All commonly used induction agents will cause hypotension, particularly when a full dose is administered to a volume-constricted patient. Dosage recommendations for RSI induction agents are largely based on patients without hemodynamic instability. As such, in trauma patients with hypotension or a shock index greater than 0.8, it seems prudent that the dose of the induction agent be reduced by at least 50%.[83,91,95,99] In North America, etomidate has been the most commonly used induction agent used for RSI. Owing to the association between using etomidate and adrenal suppression, many institutions have moved to alternative induction agents.[1,100] With a favorable hemodynamic profile and strong analgesic effect, ketamine is quickly becoming the preferred induction agent for trauma patients.[100] A study comparing standard full-dose ketamine with etomidate in trauma patients showed no survival benefit of one agent over the other.[100] In light of this, it is probably true to suggest that *the dose of the drug is more important than the choice of drug*.

Paralysis should have no direct effect on the patient's hemodynamic status, and in hypoperfused states their dose should be increased. There is some debate regarding which neuromuscular blocking agent is superior for an RSI: both succinylcholine and rocuronium may be safely used and can provide good intubating conditions.[101] It should be emphasized, however, that administering too small a dose (<1.0 mg/kg) of rocuronium, particularly in low-flow states, will result in inadequate intubating conditions and a larger dose is recommended (1.2–1.6 mg/kg).[101,102] Although clinicians may be weary of the prolonged effect of high-dose rocuronium in potentially difficult airway cases, extended, deep paralysis is in fact desirable in this circumstance, as it helps to create optimal conditions for laryngoscopy, BVM and SGA ventilation, and FONA. Having the sick trauma patient wake up to a state that he or she will be able rescue his or her own airway is simply not realistic, and will make efforts to secure the airway even more difficult.

Management of peri-intubation hemodynamic instability

- Resuscitation using blood products (packed red blood cells/massive transfusion) should be done early in the preintubation phase of trauma management.
- In selected scenarios consider the use of vasopressors during the peri-intubation phase.
- Reduce the dose of all induction agents by at least 50% and increase the dose of the paralytic.

Avoiding Hypoxemia

Hypoxemia during emergency department (ED) RSI is common, occurring in more than one-third of cases.[24] Proceeding with an RSI in a patient who is already hypoxemic can result in catastrophic complications. Patients with preintubation oxygen saturations of less than 95% are at risk of abrupt desaturation within 90 seconds of the onset of apnea.[103] Although recent literature has focused on extending safe apnea time with passive high-flow nasal oxygenation (HFNO) with or without noninvasive ventilation, the most important determinant of time to desaturation remains preoxygenation status.[104]

Although high oxygen saturation is reassuring, it is not a true measurement of oxygen reserve. Furthermore, oxygen saturation alone provides little information about the true safe apnea time, which is defined by the relationship between oxygen reserve and the rate of oxygen consumption. Effective management of the preoxygenation phase requires both increasing the patient's oxygen reserve while simultaneously decreasing the rate of oxygen consumption through aggressive resuscitation. Increasing the oxygen reserve has 3 components: denitrogenation of the lungs, recruitment of alveoli with PEEP, and apneic oxygenation.

Denitrogenation is the primary physiologic mechanism of preoxygenation and is dependent on delivery of a high concentration of oxygen, resulting in a 10-fold increase available oxygen. Increased functional residual capacity (FRC) provides an ongoing reservoir to keep hemoglobin saturated. Delivery of close to 100% oxygen for approximately 4 minutes is required to denitrogenate normal lungs and may be most easily accomplished with high-flow, "flush-rate" (40 LPM) oxygen using a conventional non-rebreather mask.[105] In patients with a high minute ventilation or shunt physiology, a closed system BVM with a PEEP valve and a tight-fitting mask is the preferred preoxygenation technique. If respiratory effort support is required, this is best achieved using a mechanical (NIV) as opposed to manual ventilator (BVM).

With atelectasis, pulmonary contusion, and other lung pathologies, the FRC is diminished and the resultant shunt physiology renders preoxygenation with a high FiO_2 less effective in preventing desaturation.[106–108] Alveolar recruitment using an oxygen delivery device with PEEP is necessary to help mitigate the negative effects of shunt physiology. A PEEP valve should be considered standard when using a BVM for preoxygenation, as it will prevent entrainment in BVMs without a dedicated expiratory valve. A PEEP valve attached to a BVM and applied over conventional nasal prongs at high flow ($\geq$15 LPM) in a spontaneously breathing patient will produce continuous positive airway pressure–like conditions. Assisted ventilations are best delivered using a dedicated noninvasive ventilator; however, can be performed with the same BVM/PEEP, nasal cannula combination. It is advisable to use a pressure manometer attached to the BVM when using this combination to minimize high pressures that may result in gastric distention and aspiration.

Alveolar oxygen delivery that continues without respiratory effort is referred to as apneic oxygenation (AO). AO is facilitated by the pressure gradient between the oropharynx and the alveoli created by the differential uptake of oxygen and delivery of CO2 to and from the alveoli, resulting in the passive transfer of oxygen.[104,107] By continuously replenishing the FRC oxygen stores, apneic oxygenation using conventional or specialized nasal prongs to administer high-flow oxygen (10–70 LPM) may extend the safe apnea time after an RSI.[103,104] Numerous studies have evaluated to effectiveness of HFNO as an adjunct to preoxygenation for RSI, and the balance of evidence suggest the procedure as both safe and effective.[104]

Of note, the ability to extend the safe apnea time must not allow providers to become cavalier and should not encourage prolonged intubation attempts.[106,109] By the time peripheral oxygen saturation begins to fall, cerebral hypoxemia has already occurred, a phenomenon known as "pulse-ox lag."[103] Effective situation awareness is required, even (and perhaps especially) when supporting gas exchange by way of passive oxygenation, to stay within the "safe apnea" zone.

Preoxygenation: "the rule of 2s"

- Elevate the head (ear to sternum) and the bed greater than 20° (reverse Trendelenburg).
- Two sources of oxygen for all critically ill patients: high-flow nasal prongs $\geq$15 L/min and NRB/bag-mask ventilation $\geq$15 L/min.
- Two approaches for obstruction: OPA with a jaw thrust for soft tissue obstruction.

- Two attachments for your BVM: positive end-expiratory pressure valve and pressure manometer.
- Two hands on all face masks: to ensure closed system oxygenation and ventilation and perform an aggressive jaw thrust.
- Two providers: the most experienced obtaining a tight mask seal and aggressive jaw thrust giving feedback to the provider squeezing the bag to avoid overventilation and hyperventilation.

Abbreviations: BVM, bag-valve-mask; NRB, non-rebreather mask; OPA, oropharyngeal airway.

FRONT OF NECK AIRWAY TO SECURE THE AIRWAY

Numerous methods are used to access the trachea infraglottically, and the terminology describing the procedure is as variable as the techniques available to do so. Perhaps most accurate is the new term "front of neck airway" (FONA), which eliminates ambiguous verbiage like "surgical airway" or "airway rescue."[110] Although rare (0.05%–1.7% of ED-based intubations), the decision to perform FONA must begin during the initial assessment of the patient's airway, long before the "cannot intubate cannot oxygenate" (CICO) scenario is encountered.[111] This begins with a pre-procedure briefing with team members to define clear triggers for moving ahead with the procedure. Palpation of the anterior neck, and perhaps even marking the anticipated location of the cricothyroid membrane should be done routinely for all emergency airway cases and equipment should be both familiar to team members and immediately available.

Cognitive and team-based preparation is vital, as the decision to proceed with a FONA is often delayed until critical hypoxemia has occurred.[111] It is widely speculated that the most significant delay is often the result of hesitant decision-making and a reluctance to perform a rarely encountered procedure.[112] Open discussion of the emergency surgical airway as a potential outcome familiarizes the team and normalizes the procedure, shifting from the negative connotation of the "failed airway" to the recognition of the ultimately inevitable surgical airway.[113] By normalizing the procedure, at least cognitively, we aim to reduce the psychological distress associated with it.

No specific oxygen saturation level should be used as a trigger to perform FONA, recognizing that a failed oxygenation situation is dynamic and characterized by a rapidly falling oxygen saturation despite maximal efforts to reoxygenate the patient.[111] Failed intubation followed by difficult mask ventilation with falling saturations represents an impending FONA that should be initiated after a single rescue attempt with supraglottic airway device. In rare situations, FONA may be the first and only invasive airway technique attempted, even in the setting of normal oxygen saturation; for example, massive facial trauma disrupting all recognizable airway landmarks. This "surgically inevitable" airway needs to be identified and declared early, such that time is not wasted on fruitless efforts to intubate "from above."

There are several options for the emergency FONA and there remains some controversy regarding the preferred approach. Historically, methods such as transtracheal jet ventilation and percutaneous cricothyroidotomy with a Seldinger technique, have been advocated. However, recent reviews have shown that complications associated with jet ventilation are unacceptably high and wire-guided approaches are not as easy or successful as once believed.[114–117]

There has been a recent push to adopt a modified open technique using a scalpel, finger, and bougie (the "scalpel-bougie" technique). The 2015 Difficult Airway Society guidelines recommend that all clinicians responsible for airway management be able to perform a FONA, and that the scalpel-bougie technique is the technique of choice.[89] The scalpel-bougie technique has several advantages for the emergency clinician: it relies on gross motor skills (which are more likely to be preserved during periods of acute stress), uses familiar equipment (scalpel, bougie, and a #6 ETT), and has a minimal number of steps.

The body of evidence for this rarely needed procedure is (and will likely remain) limited, yet all clinicians need to be mentally and technically prepared to rapidly perform front of neck access to secure the airway. Success for high-acuity, low-opportunity events like this requires frequent, deliberate practice using simulation.[118] FONA trainers need not be expensive or complicated; motor habit can be developed using simple models with Venturi oxygen tubing or an empty roll of bathroom tissue.

SUMMARY

Effective trauma care requires a team approach, with resuscitation priorities clearly communicated and interventions guided by the physiologic priorities that ensure adequate oxygen delivery. Although ensuring oxygenation and ventilation are priorities, airway management as the technical imperative of putting the "tube in the hole" must not overshadow other resuscitative elements.

Providing advanced airway management is part of the A *and* B *and* C parallel resuscitative priorities of trauma care. Safely managing both the anticipated and unanticipated difficult airway requires technical expertise; however, decisions of when and how to intervene are equally important determinants of outcome. Airway management in trauma begins as soon as patient contact is made and rarely starts with placement of an ETT. Gaining intravenous access, beginning fluid resuscitation, and applying oxygen may be lifesaving and/or bridging interventions that allow for the safe execution of downstream more definitive procedures. Whether the team is a doctor, nurse, and transporting paramedics or a group of 10, success is dependent on a shared understanding of the importance of resuscitation before intubation and clear communication of what and when various airway interventions will be performed. Then, securing the airway will have the best chance of making a positive difference in trauma patient outcomes.

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