Emergency tracheal intubation immediately following traumatic injury: An Eastern Association for the Surgery of Trauma practice management guideline

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BACKGROUND: The ABCs of trauma resuscitation begin with the airway evaluation, and effective airway management is imperative in the care of a patient with critical injury. The Eastern Association for the Surgery of Trauma Practice Management Guidelines committee aimed to update the guidelines for emergency tracheal intubation (ETI) published in 2002. These guidelines were made to assist clinicians with decisions regarding airway management for patients immediately following traumatic injury. The goals of the work group were to develop evidence-based guidelines to (1) characterize patients in need of ETI and (2) delineate the most appropriate procedure for patients undergoing ETI.

METHODS: A search of the National Library of Medicine and the National Institutes of Health MEDLINE database was performed using PubMed (www.pubmed.gov).

RESULTS: The search retrieved English-language articles published from 2000 to 2012 involving patients who had sustained blunt trauma, penetrating trauma, or heat-related injury and had developed respiratory system insufficiency or required ETI in the immediate period after injury (first 2 hours after injury). Sixty-nine articles were used to construct this set of practice management guidelines.

CONCLUSION: The data supported the formation of six Level 1 recommendations, four Level 2 recommendations, and two Level 3 recommendations. In summary, the decision to intubate a patient following traumatic injury is based on multiple factors, including the need for oxygenation and ventilation, the extent and mechanism of injury, predicted operative need, or progression of disease. Rapid sequence intubation with direct laryngoscopy continues to be the recommended method for ETI, although the use of airway adjuncts such as blind insertion supraglottic devices and video laryngoscopy may be useful in facilitating successful ETI and may be preferred in certain patient populations. There is no pharmacologic induction agent of choice for ETI; however, succinylcholine is the neuromuscular blockade agent recommended for rapid sequence intubation. (*J Trauma Acute Care Surg*. 2012;73: S333–S340. Copyright © 2012 by Lippincott Williams & Wilkins)

KEY WORDS: Guideline; endotracheal intubation; trauma; rapid sequence intubation.

The first priority in the care of all trauma patients is the affirmation of a patent airway to ensure adequate oxygenation and ventilation. The ABCs of trauma resuscitation begin with the airway evaluation, and effective airway management is imperative in the care of a patient with critical injury. Patients may require emergency tracheal intubation (ETI) for various reasons following injury including hypoxia, hypoventilation, or failure to maintain or protect the airway owing to altered mental status. However, multiple factors may be present, which make the decision to intubate less straightforward. One of the most difficult aspects of airway management in trauma is the potential deterioration in clinical status, which may occur during the early phases of resuscitation. The decision to intubate may go well beyond a patient's ability to oxygenate or ventilate.

It has long been established that any decrease in oxygen delivery to the injured brain, precipitated by hypoxia or hypotension, increases morbidity and mortality in the setting of severe traumatic brain injury.[1–6] Therefore, the decision is not only whether a patient needs intubation but also when and how to intubate. Delays in adequate airway management may have devastating consequences, and this is one of the more common causes of preventable death in both the prehospital and the emergency department setting.[7,8] Even for patients that are initially stable, a delay in intubation is associated with increased mortality from 1.8% to 11.8% in one study.[9] In addition, ETI has the potential to cause secondary injury if performed inadequately or unsuccessfully by creating or exacerbating hypoxia or hypotension.

In 2002, the Eastern Associated for the Surgery of Trauma (EAST) Practice Management Guidelines (PMGs) Committee work group on ETI formulated guidelines to assist clinicians with decisions regarding airway management for patients immediately following traumatic injury. The goals of the work group were to develop evidence-based guidelines to (1) characterize patients in need of ETI and (2) delineate the most appropriate procedure for patients undergoing ETI. The

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basis for these guidelines was an evidence-based review of patients who had sustained blunt trauma, penetrating trauma, or heat-related injury and had developed respiratory system insufficiency or required ETI in the immediate period after injury (first 2 hours after injury). The previous committee reviewed literature from 1970 to 2001 and formulated the guidelines published in 2003.[10]

In creating the updated guidelines for ETI, committee members, with recognized expertise in trauma surgery, emergency medicine, and anesthesiology, formulated specific questions to be addressed during the assessment and revision process.

1. Are the 2002 guidelines still valid, and is there any new evidence to change the level of the previous recommendations?
2. Is direct laryngoscopy (DL) still the preferred method for ETI in trauma?
3. What is the role of newly introduced airway adjuncts, such as blind insertion supraglottic devices and video laryngoscopy?
4. Are there pharmacologic agents used for intubation that should be recommended for or against in the setting of acute injury?
5. What is the role of prehospital ETI?

PROCESS

Studies appropriate for the ETI update were identified using MEDLINE. An initial database query was undertaken using the same search criteria that were used in the original PMG with citations published between January 2001 and December 2011. This included a combination of MESH headings and title words with limits to English-language, human, all ages, and all study types: *hypercarbia*, *airway obstruction*, *hypoventilation*, *aspiration*, *psychomotor agitation*, *hypoxia*, *injury*/*injuries*, *trauma*/*traumatic*, *brain*, *head*, *intubation*, *endotracheal*, *tracheostomy*, *cricothyroidostomy*, *cricothyroidotomy*, and *cricothyrotomy*. Given the specific questions posed by the work group, additional search terms were used: *video-assisted laryngoscopy*, *videolaryngoscopy*, *laryngeal mask airway*, *King LT*, *Combi-tube*, and *cricoid pressure*.

In addition to the MEDLINE search, bibliography of reviews, letters to the editor, and meta-analyses were used to identify other relevant patient investigation articles. If an article investigated trauma and medical patients, the article was included if the trauma patient cohort was at least 50% or if the study included a subgroup analysis on the specific trauma population.

The initial search identified 2,688 citations. Letters to the editor, case reports, reviews, and articles dealing with airway training using simulation were excluded. The abstracts of the remaining citations were reviewed, and those articles that did not address the issues pertinent to the questions outlined previously were further excluded. In total, 93 citations met the inclusion criteria. These were distributed to members of the committee for review, and ultimately, 69 were included in the analysis. Citations were cross-referenced to the 2002 document to ensure that no articles included in the original database were repeated. The breakdown of the 69 articles was as follows:

- Population appropriate for intubation (11 articles),
- Prehospital care (36 articles),
- Pharmacologic agents (7 articles),
- Airway adjuncts and video-assisted laryngoscopy (9 articles), and
- Other (6 articles).

Articles and recommendations were classified as described in the EAST primer on using evidence-based outcome measures to develop PMGs:

Class I: Prospective randomized controlled trial (3 articles)
Class II: Prospective clinical trial or retrospective analysis based on reliable data (13 articles)
Class III: Retrospective case series or database review (53 articles)
Level 1: The recommendation is convincingly justifiable based on the available scientific information alone. This recommendation is usually based on Class I data; however, strong Class II evidence may form the basis for a Level 1 recommendation, especially if the issue does not lend itself to testing in a randomized format.
Level 2: The recommendation is reasonably justifiable by available scientific evidence and strongly supported by expert opinion. This recommendation is usually supported by Class II data or a preponderance of Class III evidence.
Level 3: The recommendation is supported by available data but adequate scientific evidence is lacking. This recommendation is generally supported by Class III data. This type of recommendation is useful for educational purposes and in guiding future clinical research.

RECOMMENDATIONS

Airway Assessment

Level 1

There were no recommendations.

Level 2

The recommendations are as follows:

1. A careful airway assessment should be performed before initiating efforts to secure the airway. The goals of this assessment are to identify potential markers of difficulty with the following:
   a. Bag-valve mask ventilation,
   b. Laryngoscopy, and
   c. Surgical airway.
2. The application of structured assessment tools (e.g., the LEMON law) is recommended.
3. When significant difficulty is anticipated, neuromuscular blockade should be used with caution, and airway rescue devices, including surgical airway equipment, should be immediately available.

Level 3

There were no recommendations.

Scientific Foundation

The original PMGs did not include any recommendations for airway assessment. Although many emergency intubations are straightforward, as many as 0.3% to 2.7% result in "failed

airways" in the setting of trauma.[11,12] Recognition of specific attributes of the difficult airway allow for better preparation and potentially preventable adverse consequences. An assessment tool used in the current (eighth) version of advanced trauma life support is the LEMON mnemonic.[13]

L: Look externally (facial trauma, large incisors, beard or moustache, large tongue);
E: Evaluate the 3-3-2 rule (incisor distance < 3 fingers, hyoid mental distance < 3 fingers, thyroid to mouth < 2 fingers);
M: Mallampati score;
O: Obstruction (presence of any condition that could cause obstruction); and
N: Neck mobility (all patients with blunt trauma require cervical in-line stabilization that makes visualization of the glottis more difficult).

The use of the LEMON score was able to successfully stratify the risk of intubation difficulty. Patients with a high airway assessment score were found to have a poor laryngoscopic view compared with those patients with a low airway assessment score.[14]

Indications for ETI

Level 1

1. ETI is indicated in trauma patients with the following traits:
   a. Airway obstruction,
   b. Hypoventilation,
   c. Persistent hypoxemia ($SaO_2 \leq 90\%$) despite supplemental oxygen,
   d. Severe cognitive impairment (Glasgow Coma Scale [GCS] score ≤ 8),
   e. Severe hemorrhagic shock, and
   f. Cardiac arrest.

2. ETI is indicated for patients experiencing smoke inhalation with any of the following traits:
   a. Airway obstruction,
   b. Severe cognitive impairment (GCS score ≤ 8),
   c. Major cutaneous burn (≥40%),
   d. Major burns and/or smoke inhalation with an anticipated prolonged transport time to definitive care, and
   e. Impending airway obstruction as follows:
      i. Moderate-to-severe facial burn;
      ii. Moderate-to-severe oropharyngeal burn, and
      iii. Moderate-to-severe airway injury seen on endoscopy.

Level 2

There were no recommendations.

Level 3

3. ETI may also be indicated in trauma patients with any of the following traits:
   a. Facial or neck injury with the potential for airway obstruction,
   b. Moderate cognitive impairment (GCS score > 9–12),
   c. Persistent combativeness refractory to pharmacologic agents,
   d. Respiratory distress (without hypoxia or hypoventilation),
   e. Preoperative management (i.e., patients with painful injuries or undergoing painful procedures before nonemergent operation), and
   f. Early ETI is indicated in cervical spinal cord injury with any evidence of respiratory insufficiency (complete cervical SCI or incomplete injuries C5 and above).

Scientific Foundation

After publication of the original PMG guidelines on ETI, there was some debate about whether the criteria recommended for ETI after trauma (Number 1 in the previous enumeration) fully represented the trauma population that would benefit from ETI. The committee expanded the criteria that may indicate a need for ETI (Number 3 in the previous enumeration). These recommendations were based on several retrospective studies that identified the need for airway management for patients with these criteria. Sise et al.[15] performed a retrospective review of 1,000 consecutive patients that were intubated after injury. The study evaluated indications for intubation and characterized them as either those indicated by the EAST Guidelines or other discretionary indications (DI). In the study population of 1,000 patients, 44% were intubated for reasons other than those stated in the EAST guidelines. These DI included altered mental status with GCS score of greater than 8 (24.8%), combativeness (12.7%), preoperative management (4.8%), facial or neck injury (1.5%), and respiratory distress without hypoxia (0.6%). Importantly, one in three DI patients was found to have significant head injury. Despite a 12.6% rate of head injury in those patients intubated for combativeness in this study, intubation in this setting is not without risk. A study by Muakkassa et al.[16] demonstrated that patients intubated for combativeness as the only indication have longer stay, an increased incidence of pneumonia, and poorer discharge status when compared with matched controls. However, given the risk of significant head injury and the importance of being able to complete a thorough trauma evaluation, persistent combativeness that inhibits the ability to adequately evaluate potential injuries and that is refractory to safe pharmacologic management is included in the criteria for ETI.

Another patient population studied with regard to early tracheal intubation are those with cervical spinal cord injuries. Three retrospective studies with more than 400 patients support thorough evaluation of respiratory status, and those with complete SCI should be intubated early, especially with injury levels of C5 and above.[17–19] Those patients with incomplete SCI with any sign of respiratory insufficiency should also be intubated early.[17]

Patients with penetrating neck trauma are also at risk for airway compromise and increased mortality when airway management is delayed or ineffective. In addition to the data of Sise et al., multiple other studies support early ETI for patients with neck injury.[20–23] Given the risk of airway injury and potential difficulty with airway management, three studies have attempted to delineate the best approach for airway control in this patient population.[21–23] Although none was able to make definitive recommendations for the best method of obtaining ETI, these studies support either DL or awake nasotracheal intubation. In these situations, there are no definitive recommendations as to where ETI should take place, whether

in the trauma bay or in the operating room. This decision is made by the trauma surgeon in charge based on airway stability, anticipation of difficult airway management, and available personnel.

Procedural Options

Level 1

1. Orotracheal intubation guided by DL is the ETI procedure of choice for trauma patients.
2. Rapid sequence intubation (RSI) should be used to facilitate orotracheal intubation unless markers of significant difficulty with intubation are present. An RSI drug regimen should be given to achieve the following clinical objectives:
   a. Adequate sedation and neuromuscular blockade,
   b. Maintenance of hemodynamic stability and CNS perfusion,
   c. Maintenance of adequate oxygenation,
   d. Prevention of increases in intracranial hypertension, and
   e. Prevention of vomiting and aspiration.

There are no recommendations regarding the use of specific induction agents used for RSI in trauma. Succinylcholine is the recommended agent of choice for neuromuscular blockade, in the absence of any contraindications to its use.

3. Enhancements for safe and effective ETI in trauma patients include the following:
   a. Availability of experienced personnel,
   b. Pulse-oximetry monitoring,
   c. Maintenance of cervical neutrality,
   d. Confirmation of tube placement using auscultation of bilateral breath sounds and end-tidal CO_2 detection, and
   e. Continuous end-tidal CO_2 monitoring for patients with severe traumatic brain injury.
4. Cricothyroidostomy is appropriate when emergent/urgent tracheal intubation is needed and cannot be achieved rapidly with DL or with the use of alternative airway techniques and devices.

Level 2

5. When ETI cannot be achieved rapidly with DL, a number of airway rescue devices may be used as follows:
   a. Blind-insertion supraglottic devices (i.e., LMA, Combitube, and King Airway),
   b. Gum-elastic bougie,
   c. Video laryngoscopy, and
   d. Surgical cricothyroidostomy.

Decisions regarding the most appropriate rescue technique should be guided by the clinical scenario at hand, resource availability, and the skill and experience of the treating clinician.

Level 3

6. Video laryngoscopy may offer significant advantages over DL, including the following:
   a. Superior views of the glottis (Cormack-Lehane I/II);
   b. Higher intubation success rates for patients with anatomically difficult airways, in obese patients, and in those with the cervical spine held in-line; and
   c. Higher intubation success rates by inexperienced airway providers.

Scientific Foundation

RSI is the preferred method of airway management for most of the injured trauma patients. RSI provides rapid unconsciousness (induction) and neuromuscular blockade (paralysis). This is especially important in trauma patients who likely are not fasted and are at much greater risk for vomiting and aspiration. This method has been proven safe and effective during the past several decades and is considered standard of care for emergency airway management. The choice of pharmacologic agents used for RSI, however, is less straightforward. Multiple factors, such as hemodynamic instability, the presence of traumatic brain injury, or comorbid conditions, may alter the use of specific pharmacologic agents.

After careful review of the literature, the committee decided not to make recommendations on the use of specific pharmacologic agents for induction during RSI. In many centers, etomidate is the drug of choice for induction because of its rapid onset, hemodynamic stability, and extensive experience with its use. The use of etomidate for induction has been the source of much controversy and has been studied specifically in trauma patients. Single-dose etomidate has been associated with adrenal insufficiency,[24] as well as increased incidence of adult respiratory distress syndrome and multiple-organ dysfunction syndrome[25] Despite these two retrospective reviews, the evidence is not strong enough to recommend against its use. Ketamine has long been avoided for induction in patients suspected of traumatic brain injury because of a theoretical increase in intracranial pressure (ICP). Multiple reviews and editorials have questioned this historical bias.[26,27] In addition, several studies have assessed the use of ketamine as a sedative agent and its effect on ICP, some demonstrating actual decreases in ICP.[28,29] There are no convincing studies evaluating the effects of ketamine on ICP when used as an induction agent. Ketamine may be a preferable agent for patients in shock because it may actually increase blood pressure in normotensive or hypotensive patients. A review of other possible induction agents used for intubation after trauma is available.[30]

The use of a neuromuscular blocking agent (NMBA) is a fundamental part of RSI. Succinylcholine remains the agent of choice in trauma because of its consistently rapid onset and short duration of action. There is no evidence that the fasciculations caused by succinylcholine cause significant increases in ICP for patients with traumatic brain injury, and there is no support for giving defasciculating doses of nondepolarizing NMBAs.[31] Suspected elevation of ICP is not a contraindication for the use of succinylcholine. For patients with a contraindication to succinylcholine, such as prolonged immobilization, chronic kidney disease, or skeletal muscle myopathies, high-dose rocuronium is the preferred alternative.

Although a standard of care in emergency intubations, the efficacy of cricoid pressure (CP) has recently been questioned. Its introduction into clinical practice followed a description of the technique and small case series[32] and was never subject

to rigorous evaluation. The technique is used in theory to reduce the risk of aspiration during the induction phase of anesthesia, although its application, timing, and technique are not standardized. Recent evidence suggests that CP impairs laryngoscopic view, reduces bag-valve mask ventilation efficiency, and does not prevent aspiration.[33] In a prospective, observational study of 400 adult trauma patients intubated with CP, researchers compared the effect on laryngoscopic view of three maneuvers (release of CP, BURP, and laryngeal manipulation under direct vision). Removing CP facilitated intubation in most cases and was not associated with a worsening view of the glottis in any case.[34] The authors reported only two cases of regurgitation associated with failed intubation, prolonged BVM, and the removal of CP. The current recommendation is that early removal of CP in cases of poor laryngeal view will likely facilitate intubation with minimal risk to the patient. Because of this controversy and lack of evidence base, the application of CP was removed as a Level 1 recommendation.

Since the 1980s, when the use of the LMA was first reported, the use of supraglottic airway devices has become increasingly popular. Currently, multiple versions of the LMA, the Combitube, and the King Airway (LT, LTS, and LTS-D) are available. Benefits of supraglottic devices are that they can be placed blindly, rapidly, and the performance of these devices is not affected by the patient characteristics that negatively affect mask ventilation, laryngoscopy and successful performance of cricothyroidotomy (obesity, limited neck movement, facial hair, etc.). In a large study of prehospital airway management, alternate airway insertions (primarily the Combitube) occurred in 96 of 100,000 patient care events with a success rate of 87.2%.[35] Other studies using the Combitube as a rescue device for failed ETI show success rates of 95%.[36] Studies with the King airway show success rates of 92% to 100%,[37–39] and 96% of participants in one study preferring the King to the Combitube.[39]

The exact role for supraglottic devices compared with prehospital DL is unclear. A review of five controlled clinical trials with more than 1,500 patients comparing ETI with alternative airway techniques was unable to show a difference in outcome.[40] The high variability in prehospital provider competence and experience make recommendations for a specific rescue device a challenge. Based on the available data, it seems that supraglottic airway devices show an acceptable success rate as primary and rescue airway adjuncts.

DL by trained physicians, with the use of in-line stabilization for cervical spine protection, has been shown to be a safe and effective means of intubation after trauma.[41–45] Despite good success rates with DL, the use of video laryngoscopy and the studies evaluating its use have been increasing. So far, there is inconclusive evidence indicating that video laryngoscopy should replace DL in trauma patients requiring ETI. Several studies in nontrauma patients have investigated various types of video laryngoscopes (i.e., Glidescope, Bullard, Airtraq, and Pentax AWS). The specific features and characteristics of the video laryngoscopes vary, but they each provide an indirect view of the upper airway and a theoretical advantage in minimizing cervical spine motion during intubation. Studies have supported that the Cormack-Lehane grade is improved,[46–48] cervical spine motion is lessened,[49–52] force and pressures exerted on the airway are decreased,[53,54] hemodynamic responses are minimized,[55] and time to intubation is similar[56] with video as compared with DL. One study specifically looking at patients intubated with cervical spine immobilization by a semirigid collar showed improved views with the Glidescope over a Macintosh blade.[57] However, improved laryngeal views are not always matched with higher intubation success rate. Despite the good visualization of the glottis, the insertion and advancement of the endotracheal tube may occasionally fail, and despite the growing evidence that video laryngoscopy may be superior to DL in some cases, many of these studies are performed in cadaver models, simulation scenarios, and elective nontrauma patients and performed by personnel well trained with the use of the devices. One retrospective study of 822 emergency department intubations (of which, >60% were trauma patients) showed that overall success rates for video laryngoscopy were similar to DL, but first-attempt success rates were higher using the Glidescope.[58] Another emergency department–based review also showed similar overall success rates but an increased time to completion when the Glidescope was used compared with DL.[59]

Video-assisted devices may have a greater role for patients with potentially difficult airways. Studies performed in patients with easy laryngoscopy (Cormack-Lehane grade I or II) demonstrate similar success rates as DL but increased time to intubation.[49,60,61] The benefit is more measurable for patients with difficult airways, where DL may not provide good visualization.[60,62,63] Further studies, looking specifically at trauma patients, need to be performed before further recommendations may be made regarding the use of video laryngoscopy for ETI.

Areas for Future Investigation

Prehospital ETI

The subject with the most literature and the most Level 1 and Level 2 data is regarding the role of prehospital intubation in trauma. Of the 69 articles reviewed for this PMG, 31 involved this perplexing question. Many studies support improved functional outcomes for those receiving ETI in the field,[64–71] but as many demonstrate delays in transport to definitive care and similar or worse outcome.[72–84] More specifically, some studies evaluated the benefit of RSI versus intubation without RSI[70,85–90] However, despite the plethora of data, literature reviews,[91–93] as well as expert panels formed to attack this particular question,[94] no conclusion could be reached regarding prehospital intubation for patients with traumatic brain injury, with or without RSI. Diversity of patient population, differing airway algorithms, various experience among emergency medical service personnel in ETI, and differing reporting make consensus difficult. Until further multicenter prospective studies are performed, local emergency medical service directors must evaluate local factors to ensure optimal outcome for patients meeting this criteria.

This review also did not take into consideration specific pediatric trauma airway considerations. The committee thought as though the scope of experience as well as the lack of significant data made recommendations in this area beyond this committee's expertise.

Key Points

- The decision to intubate a patient following traumatic injury is based on multiple factors including not only the need for oxygenation and ventilation but also mechanism of injury, predicted operative need, or progression of disease (i.e., burns, spinal cord injury).
- ETI is best achieved by an RSI technique with DL.
- There is no pharmacologic induction agent of choice for ETI.
- Succinylcholine is the NMBA of choice for paralysis for ETI.
- The use of CP is no longer a Level 1 recommendation.
- Airway adjuncts may be useful in facilitating successful ETI.

DISCLOSURE

The authors declare no conflicts of interest.

REFERENCES

1. Katsurada K, Yamada R, Sugimoto T. Respiratory insufficiency in patients with severe head injury. *Surgery.* 1973;73:191–199.
2. Miller JD, Butterworth JF, Gudeman SK, et al. Further experience in the management of severe head injury. *J Neurosurg*. 1981;54:289–299.
3. Wald SL, Shackford SR, Fenwick J. The effect of secondary insults on mortality and long-term disability after severe head injury in a rural region without a trauma system. *J Trauma*. 1993;34:377–381.
4. Stocchetti N, Furlan A, Volta F. Hypoxemia and arterial hypotension at the accident scene in head injury. *J Trauma*. 1996;40:764–767.
5. Davis DP, Meade W, Sise MJ, et al. Both hypoxemia and extreme hyperoxia may be detrimental in patients with severe traumatic brain injury. *J Neurotrauma*. 2009;26:2217–2223.
6. Chesnut RM, Marshall LF, Klauber MR, et al. The role of secondary brain injury in determining outcome from severe brain injury. *J Trauma*. 1993; 34:216–222.
7. Esposito TJ, Sanddal ND, Hansen JD, et al. Analysis of preventable deaths and inappropriate trauma care in a rural state. *J Trauma*. 1995;39:955–962.
8. Teixeira PGR, Inaba K, Hadijizacharia P, et al. Preventable or potentially preventable mortality at a mature trauma center. *J Trauma*. 2007;63: 1638–1650.
9. Miraflor E, Chuan K, Miranda MA, et al. Timing is everything: delayed intubation is associated with increased mortality in initially stable trauma patients. *J Surg Res*. 2011;170:117–121.
10. Dunham CM, Barraco RD, Clark DE, et al. Guidelines for emergency tracheal intubation immediately following traumatic injury. *J Trauma*. 2003;55:162–179.
11. Bair AE, Rilbin MR, Kulkarni RG, et al. The failed intubation attempt in the emergency department: analysis of prevalence, rescue techniques, and personnel. *J Emerg Med*. 2002;23:131–140.
12. Stephens CT, Kahntroff S, Dutton R. The success of emergency endotracheal intubation in trauma patients: a 10-year experience at a major adult trauma referral center. *Anesth Analg*. 2009;109:866–872.
13. Kortbeek JB, Turki SA, Ali J, et al. Advanced trauma life support, 8th edition, the evidence of change. *J Trauma*. 2008;64:1638–1650.
14. Reed MJ, Dunn MJ, McKeown DW. Can an airway assessment score predict difficulty at intubation in the emergency department? *Emerg Med J*. 2005;22:99–102.
15. Sise MJ, Shackford SR, Sise CB, et al. Early intubation in the management of trauma patients: indications and outcomes in 1,000 consecutive patients. *J Trauma*. 2009;66:32–39.
16. Muakkassa FF, Marley RA, Workman, MC, et al. Hospital outcomes and disposition of trauma patients who are intubated because of combativeness. *J Trauma*. 2010;68:1305–1309.
17. Hassid VJ, Schinco MA, Tepas J, et al. Definitive establishment of airway control is critical for optimal outcome in lower cervical spinal cord injury. *J Trauma*. 2008;65:1328–1332.
18. Como JJ, Sutton ER, McCunn M, et al. Characterizing the need for mechanical ventilation following cervical spinal cord injury with neurologic deficit. *J Trauma*. 2005;59:912–916.
19. Velmahos GC, Toutouzas K, Chan L, et al. Intubation after cervical spinal cord injury: to be done selectively or routinely? *Am Surg*. 2003;69: 891–894.
20. Rajani RR, Ball CG, Montgomery SP, et al. Airway management for victims of penetrating trauma: analysis of 50,000 cases. *Am J Surg*. 2009; 198:863–867.
21. Kummer C, Netto FS, Rizoli S, et al. A review of trauma airway injuries: potential implications for airway assessment and management. *Injury.* 2007;38:27–33.
22. Tallon JM, Ahmed, JM, Sealy B. Airway management in penetrating neck trauma at a Canadian tertiary trauma center. *CJEM*. 2007;9:101–104.
23. Weitzel N, Kendall J, Pons P. Blind nasotracheal intubation for patients with penetrating neck trauma. *J Trauma*. 2004;56:1097–1101.
24. Cotton BA, Guillamondegui OD, FLemin SB, et al. Increased risk of adrenal insufficiency following etomidate exposure in critically injured patients. *Arch Surg*. 2008;143:62–67.
25. Warner KJ, Cuschieri J, Jurkovich GJ, et al. Single-dose etomidate for rapid sequence intubation may impact outcome after severe injury. *J Trauma*. 2009;67:45–50.
26. Filanovsky Y, Miller P, Kao J. Myth: ketamine should not be used as an induction agent for intubation in patients with head injury. *CJEM*. 2010;12:154–157.
27. Sehdev RS, Symmons DA, Kindl K. Ketamine for rapid sequence induction in patients with head injury in the emergency department. *Emerg Med Australas*. 2006;18:37–44.
28. Mayberg TS, Lam AM, Matta BF, et al. Ketamine does not increase cerebral blood flow velocity or intracranial pressure during isoflurane/ nitrous oxide anesthesia in patients under-going craniotomy. *Anesth Analg*. 1995;81:84–89.
29. Bar-Joseph G, Guliburd Y, TAmir A, et al. Effectiveness of ketamine in decreasing intracranial pressure in children with intracranial hypertension. *J Neurosurg Pediatr*. 2009;4:40–46.
30. Fields AM, Rosbolt MB, Cohn SM. Induction agents for intubation of the trauma patient. *J Trauma*. 2009;67:867–869.
31. Clancy M, Halford S, Walls R, et al. In patients with head injuries who undergo rapid sequence intubation using succinylcholine, does pretreatment with a competitive neuromuscular blocking agent improve outcome? A literature review. *Emerg Med J*. 2000;18:373–375.
32. Selick BA. Cricoid pressure to control regurgitation of stomach contents during induction of anesthesia. *Lancet*. 1961;2:404–406.
33. Ellis DY, Harris T, Zideman D. Cricoid pressure in emergency department rapid sequence intubations: a risk-benefit analysis. *Ann Emerg Med*. 2007; 50:653–665.
34. Harris T, Ellis, DY, Foster L, et al. Cricoid pressure and laryngeal manipulation in 402 pre-hospital emergency anaesthetics: essential safety measure or a hindrance to rapid safe intubation? *Resuscitation*. 2010;81: 810–816.
35. Wang HE, Mann NC, Mears G, et al. Out of hospital airway management in the United States. *Resuscitation*. 2011;82:378–385.
36. Davis DP, Valentine C, Ochs M, et al. The Combitube as a salvage airway device for paramedic rapid sequence intubation. *Ann Emerg Med*. 2003;42: 697–704.
37. Russi CS, Hartley JM, Buresh CT. A pilot study of the King LT supralaryngeal airway use in a rural Iowa EMS system. *Int J Emerg Med*. 2008;1:135–138.
38. Guyette FX, Wang H, Cole JS. King airway use by air medical providers. *Prehosp Emerg Care*. 2007;11:473–476.
39. Tumpach EA, Lutes M, Ford D, et al. The King LT versus the Combitube: flight crew performance and preference. *Prehosp Emerg Care*. 2009;13: 324–328.
40. Jensen JL, Cheung KW, Tallon JM, et al. Comparison of tracheal intubation and alternative airway techniques performed in the prehospital setting by paramedics: a systematic review. *CJEM*. 2010;12:135–140.
41. Manoach S, Paladino L. Manual in-line stabilization for acute airway management of suspected cervical spine injury: historical review and current questions. *Ann Emerg Med*. 2007;50:236–245.

42. Ollerton JE, Parr MJ, Harrison K, Hanrahan B, Sugrue M. Potential cervical spine injury and difficult airway management for emergency intubation of trauma adults in the emergency department—a systematic review. *Emerg Med J*. 2006;23:3–11.
43. Patterson H. Emergency department intubation of trauma patients with undiagnosed cervical spine injury. *Emerg Med J*. 2004;21:302–305.
44. Bushra JS, McNeil B, Wald DA, Schwell A, Karras DJ. A comparison of trauma intubations managed by anesthesiologists and emergency physicians. *Acad Emerg Med*. 2004;11:66–70.
45. Stephens CT, Kahntroff S, Dutton RP. The success of emergency endotracheal intubation in trauma patients: a 10-year experience at a major adult trauma referral center. *Anesth Analg*. 2009;109:866–872.
46. Stroumpoulis K, Pagoulatou A, Biolari M, et al. Videolaryngoscopy in the management of the difficult airway: a comparison with the Macintosh blade. *Eur J Anaesthesiol*. 2009;26:218–222.
47. Kaplan MB, Hagverg CA, Ward DS, et al. Comparison of direct and video-assisted views of the larynx during routine intubation. *J Clin Anesth*. 2006;18:357–362.
48. Brown CA, Bair AE, Pallin DJ, et al. Improved glottic exposure with the video Macintosh laryngoscope in adult emergency department tracheal intubations. *Ann Emerg Med*. 2010;56:83–88.
49. Malik MA, Maharaj CH, Harte BH, et al. Comparison of Macintosh, Truview EVO2, Glidescope, and Airwayscope laryngoscope use in patients with cervical spine immobilization. *Br J Anaesth*. 2008;101:723–730.
50. Komatsu R, Kamata K, Hoshi I, et al. Airway scope and gum elastic bougie with Macintosh laryngoscope for tracheal intubation in patients with simulated restricted neck mobility. *Br J Anaesth*. 2008;101:863–869.
51. Maruyama K, Yamada T, Kawakami R, et al. Randomized cross-over comparison of cervical spine motion with the AirWay Scope or Macinstosh laryngoscope with in-line stabilization: a video-flouroscopic study. *Br J Anaesth*. 2008;101:563–567.
52. Maruyama K, Yamada T, Kawakami R, et al. Upper cervical spine movement during intubation: fluoroscopic comparison of the Airway Scope, McCoy laryngoscope, and Macintosh laryngoscope. *Br J Anaesth*. 2008; 100:120–124.
53. Carassitia M. Force and pressure distribution using Macintosh and Glidescope laryngoscopy in normal and difficult airways: a manikin study. *Br J Anaesth*. 2012;108:146.
54. Russell T, Lee C, Firat M, et al. A comparison of the forces applied to a manikin during laryngoscopy with the Glidescope and Macintosh laryngoscopes. *Anaesth Intensive Care*. 2011;39:1098–1102.
55. Koyama Y. Comparison of haemodynamic responses to tracheal intubation using the Airway scope and Macintosh laryngoscope in normotensive and hypertensive patients. *Anaesthesia*. 2011;66:895.
56. Zamora JE, Nolan RL, Sharan S, et al. Comparison of Macintosh, Truview EVO2, Glidsceope, and Airwayscope laryngoscope use in patients with cervical spine immobilization. *Br J Anaesth*. 2008;101:723–730.
57. Bathory I, Franscarolo P, Kern C, et al. Evaluation of the Glidescope for tracheal intubation in patients with cervical spine immobilization by a semi-rigid collar. *Anesth*. 2009;64:1337–1341.
58. Sakles JC, Mosier JM, Chiu S, et al. Tracheal intubation in the emergency department: a comparison of Glidescope video laryngoscopy to direct laryngoscopy in 822 intubations. *J Emer Med*.
59. Platts-Mills TF, Campagne D, Chinnock B, et al. A comparison of Glidescope video laryngoscopy versus direct laryngoscopy intubation in the emergency department. *Acad Emerg Med*. 2009;16:866–871.
60. Sun DA, Warriner CB, Parsons DG, et al. The Glidescope video laryngoscope: randomized clinical trial in 200 patients. *Br J Anaesth*. 2005;94:381–384.
61. Enomoto Y, Asai T, Arai T, et al. Pentax-AWS, a new videolaryngoscope, is more effective than the Macintosh laryngoscope for tracheal intubation in patients with restricted neck movements. *Br J Anaesth*. 2008;100: 544–548.
62. Asai T, Liu EH, Matsumoto S, et al. Use of the Pentax-AWS in 293 patients with difficult airways. *Anesthesiology*. 2009;110:898–904.
63. Lim HC, Goh SH. Utilization of a Glidescope videolaryngoscope for orotracheal intubations in different emergency airway management settings. *Eur J Emerg Med*. 2009;16:68–73.
64. Bernard SA, Nguyen V, Cameron P, et al. Prehospital rapid sequence intubation improves functional outcome for patients with severe traumatic brain injury: a randomized controlled trial. *Ann Surg*. 2010;252:959–965.
65. Bernard S, Smith K, Foster S, Hogan P, Patrick I. The use of rapid sequence intubation by ambulance paramedics for patients with severe head injury. *Emerg Med (Fremantle)*. 2002;14:406–411.
66. Bulger EM, Nathens AB, Rivara FP, Moore M, MacKenzie EJ, Jurkovich GJ. Management of severe head injury: institutional variations in care and effect on outcome. *Crit Care Med*. 2002;30:1870–1876.
67. Fakhry SM, Scanlon JM, Robinson L, et al. Prehospital rapid sequence intubation for head trauma: conditions for a successful program. *J Trauma*. 2006;60:997–1001.
68. Franschman G, Peerdeman SM, Greuters S, et al. Prehospital endotracheal intubation in patients with severe traumatic brain injury: guidelines versus reality. *Resuscitation*. 2009;80:1147–1151.
69. Helm M, Hauke J, Lampl L. A prospective study of the quality of pre-hospital emergency ventilation in patients with severe head injury. *Br J Anaesth*. 2002;88:345–349.
70. Ochs M, Davis D, Hoyt D, Bailey D, Marshall L, Rosen P. Paramedic-performed rapid sequence intubation of patients with severe head injuries. *Ann Emerg Med*. 2002;40:159–167.
71. Poste JC, Davis DP, Ochs M, et al. Air medical transport of severely head-injured patients undergoing paramedic rapid sequence intubation. *Air Med J*. 2004;23:36–40.
72. Bochicchio GV, Ilahi O, Joshi M, Bochicchio K, Scalea TM. Endotracheal intubation in the field does not improve outcome in trauma patients who present without an acutely lethal traumatic brain injury. *J Trauma*. 2003;54:307–311.
73. Bukur M, Kurtovic S, Berry C, et al. Pre-hospital intubation is associated with increased mortality after traumatic brain injury. *J Surg Res*. 2011; 170:e117–e121.
74. Combes X, Jabre P, Jbeili C, et al. Prehospital standardization of medical airway management: incidence and risk factors of difficult airway. *Acad Emerg Med*. 2006;13:828–834.
75. Cudnik MT, Newgard CD, Wang H, Bangs C, Herringtion R. Endotracheal intubation increases out-of-hospital time in trauma patients. *Prehosp Emerg Care*. 2007;11:224–229.
76. Davis DP, Peay J, Sise MJ, et al. The impact of prehospital endotracheal intubation on outcome in moderate to severe traumatic brain injury. *J Trauma*. 2005;58:933–939.
77. Davis DP, Stern J, Sise MJ, Hoyt DB. A follow-up analysis of factors associated with head-injury mortality after paramedic rapid sequence intubation. *J Trauma*. 2005;59:486–490.
78. Davis DP, Hoyt DB, Ochs M, et al. The effect of paramedic rapid sequence intubation on outcome in patients with severe traumatic brain injury. *J Trauma*. 2003;54:444–453.
79. Domeier RM, Fredericksen SM, Chudnofsky CF, et al. The effect of paramedic rapid-sequence intubation on outcome in trauma patients. *Prehosp Emerg Care*. 2005;9:114–115.
80. Dunford JV, Davis DP, Ochs M, Doney M, Hoyt DB. Incidence of transient hypoxia and pulse rate reactivity during paramedic rapid sequence intubation. *Ann Emerg Med*. 2003;42:721–728.
81. Katz SH, Falk JL. Misplaced endotracheal tubes by paramedics in an urban emergency medical services system. *Ann Emerg Med*. 2001;37: 32–37.
82. Shafi S, Gentilello L. Pre-hospital endotracheal intubation and positive pressure ventilation is associated with hypotension and decreased survival in hypovolemic trauma patients: an analysis of the National Trauma Data Bank. *J Trauma*. 2005;59:1140–1145; discussion 1145–1147.
83. Stockinger ZT, McSwain NE Jr. Prehospital endotracheal intubation for trauma does not improve survival over bag-valve-mask ventilation. *J Trauma*. 2004;56:531–536.
84. Wang HE, Peitzman AB, Cassidy LD, Adelson PD, Yealy DM. Out-of-hospital endotracheal intubation and outcome after traumatic brain injury. *Ann Emerg Med*. 2004;44:439–450.
85. Bulger EM, Copass MK, Sabath DR, Maier RV, Jurkovich GJ. The use of neuromuscular blocking agents to facilitate prehospital intubation does not impair outcome after traumatic brain injury. *J Trauma*. 2005;58: 718–723; discussion 723–714.

86. Bulger EM, Copass MK, Maier RV, Larsen J, Knowles J, Jurkovich GJ. An analysis of advanced prehospital airway management. *J Emerg Med*. 2002;23:183–189.
87. Christensen EF, Hoyer CC. Prehospital tracheal intubation in severely injured patients: a Danish observational study. *BMJ*. 2003;327:533–534.
88. Cudnik MT, Newgard CD, Daya M, Jui J. The impact of rapid sequence intubation on trauma patient mortality in attempted prehospital intubation. *J Emerg Med*. 2010;38:175–181.
89. Davis DP, Ochs M, Hoyt DB, Bailey D, Marshall LK, Rosen P. Paramedic administered neuromuscular blockade improves prehospital intubation success in severely head-injured patients. *J Trauma*. 2003;55:713–719.
90. Lockey D, Davies G, Coats T. Survival of trauma patients who have prehospital tracheal intubation without anaesthesia or muscle relaxants: observational study. *BMJ*. 2001;323:141.
91. Hubble MW, Brown L, Wilfong DA, Hertelendy A, Benner RW, Richards ME. A meta-analysis of prehospital airway control techniques part I: orotracheal and nasotracheal intubation success rates. *Prehosp Emerg Care*. 2010;14:377–401.
92. Sen A, Nichani R. Best evidence topic report. Prehospital endotracheal intubation in adult major trauma patients with head injury. *Emerg Med J*. 2005;22:887–889.
93. von Elm E, Schoettker P, Henzi I, Osterwalder J, Walder B. Pre-hospital tracheal intubation in patients with traumatic brain injury: systematic review of current evidence. *Br J Anaesth*. 2009;103:371–386.
94. Davis DP, Fakhry SM, Wang H, et al. Paramedic rapid sequence intubation for severe traumatic brain injury: perspectives from an expert panel. *Prehosp Emerg Care*. 2007;11:1–8.