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Guidelines for Emergency Tracheal Intubation Immediately after Traumatic Injury

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REFERRALS TO THE EAST WEB SITE

Because of the large size of the guidelines, specific sections have been deleted from this article, but are available on the Eastern Association for the Surgery of Trauma (EAST) Web site (www.east.org/trauma practice guidelines/Emergency Tracheal Intubation Following Traumatic Injury).

I. STATEMENT OF THE PROBLEM

Hypoxia and obstruction of the airway are linked to preventable and potentially preventable acute trauma deaths.[1–4] There is substantial documentation that hypoxia is common in severe brain injury and worsens neurologic outcome.[5–13] The primary concern with acute postinjury respiratory system insufficiency is hypoxemic hypoxia and subsequent hypoxic encephalopathy or cardiac arrest. A secondary problem from acute postinjury respiratory system insufficiency is hypercarbia and attendant cerebral vasodilation or acidemia. An additional concern with acute postinjury respiratory system insufficiency is aspiration and the development of hypoxemia, pneumonia, or acute respiratory distress syndrome (ARDS) and acute lung injury.

The primary categories of respiratory system insufficiency are airway obstruction, hypoventilation, lung injury, and impaired laryngeal reflexes. The physiologic sequelae of airway obstruction and hypoventilation are hypoxemia and hypercarbia. Adverse physiologic responses of lung injury and impaired laryngeal reflexes are nonhypercarbic hypoxemia and aspiration, respectively. Airway obstruction can occur with cervical spine injury, severe cognitive impairment (Glasgow Coma Scale [GCS] score ≤ 8), severe neck injury, severe maxillofacial injury, or smoke inhalation. Hypoventilation can be found with airway obstruction, cardiac arrest, severe cognitive impairment, or cervical spinal cord injury. Aspiration is likely to occur with cardiac arrest, severe cognitive impairment, or severe maxillofacial injury. A major clinical concern with thoracic injury is the development of nonhypercarbic hypoxemia. Lung injury and nonhypercarbic hypoxemia are also potential sequelae of aspiration.

Trauma patients requiring emergency tracheal intubation are critically injured; however, the degree of injury is variable. The mean study Injury Severity Score (ISS) is 29; however, the range varies from 17 to 54.[14–34] The average study GCS score for trauma patients undergoing emergency tracheal intubation is 6.5; however, the GCS score varies across its spectrum (3–15).[16–20,24,26–28,30,31,33–51] The mean study mortality rate for emergency tracheal intubation in trauma patients is 41%, yet it ranges from 2% to 100%.[14–18,20–33,35,37,39,42,44,46,47,52–69]

There is substantial variation in the percentages of trauma patients undergoing emergency tracheal intubation among and between aeromedical, ground Emergency Medical Services (EMS), and trauma center settings. For aeromedical settings, the percentage of patients undergoing tracheal intubation is 18.5%; however, the variation among studies ranges from 6% to 51%.[23,36,38,70–75] The ground EMS studies indicate that the rate of patients undergoing tracheal intubation is 4.0%, but varies from 2% to 37%.[28,29,76–79] For trauma center settings, the percentage of patients undergoing tracheal intubation is 24.5%; however, the variation among studies ranges from 9% to 28%.[14,17,40,62,80,81] Studies describing patients managed by ground EMS crews and a receiving trauma center staff indicate that the rate of tracheal intubation is 13.6%, but varies from 11% to 30%.[19,22,67,82]

It is clear that trauma patients with acute respiratory system insufficiency commonly have critical injuries, may need tracheal intubation, and develop adverse clinical outcomes. However, there is substantial variation in injury severity, mortality rates, and frequency of intubation. An evi-

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dence-based literature review was performed to identify acutely injured trauma patients who need emergency tracheal intubation and to determine the optimal procedure for tracheal intubation.

II. GOALS AND OBJECTIVES

See the EAST Web site (www.east.org/trauma practice guidelines/Emergency Tracheal Intubation Following Traumatic Injury).

III. PROCESS

See the EAST Web site (www.east.org/trauma practice guidelines/Emergency Tracheal Intubation Following Traumatic Injury).

IV. RECOMMENDATIONS TO CHARACTERIZE PATIENTS IN NEED OF EMERGENCY TRACHEAL INTUBATION IMMEDIATELY AFTER TRAUMATIC INJURY

Level I

Level I recommendations are typically predicated on evidence from randomized, controlled trials. The relevant literature is devoid of randomized, controlled trials and has been comprehensively reviewed to find the best available evidence. The recommendations are based on several peer-reviewed journal publications from institutions throughout the United States and are typically supported in multiple professional organization and society publications. The committee did not find alternative management strategies that were as effective as the recommendations. In summary, the committee consensus finds the recommendations to reflect management principles with a high degree of certainty.

1. Emergency tracheal intubation is needed in trauma patients with the following traits:
   a) airway obstruction
   b) hypoventilation
   c) severe hypoxemia (hypoxemia despite supplemental oxygen)
   d) severe cognitive impairment (GCS score $\leq$ 8)
   e) cardiac arrest
   f) severe hemorrhagic shock
2. Emergency tracheal intubation is needed in smoke inhalation patients with the following conditions:
   a) airway obstruction
   b) severe cognitive impairment (GCS score $\leq$ 8)
   c) major cutaneous burn ($\geq$40%)
   d) prolonged transport time
   e) impending airway obstruction:
      i. Moderate to severe facial burn
      ii. Moderate to severe oropharyngeal burn
      iii. Moderate to severe airway injury seen on endoscopy

V. SCIENTIFIC FOUNDATION TO CHARACTERIZE PATIENTS IN NEED OF EMERGENCY TRACHEAL INTUBATION IMMEDIATELY AFTER TRAUMATIC INJURY

A. Evidence that Trauma Patients with Airway Obstruction Need Emergency Tracheal Intubation

Background

There is documentation that patients with cervical spine injury can have airway obstruction secondary to cervical hematoma.[83–86] The need for emergency tracheal intubation in these patients with cervical spine injury is 22% (range, 14–48%).[41,63,87–89] There is also substantial documentation that patients with other severe neck injuries may have airway obstruction secondary to cervical hematoma and laryngeal or tracheal injury.[90–108]

Additional literature indicates that patients with severe neck injury have airway obstruction and commonly need emergency tracheal intubation (11–100%).[52,57,58,64,68,109–120] Specifically, patients with laryngotracheal injury frequently have airway obstruction or respiratory distress, and the majority require emergency tracheal intubation.[52,57,58,111,113–120] The literature also indicates that patients with severe maxillofacial injury can have airway obstruction and frequently need emergency tracheal intubation.[121–128]

Other patients with severe cognitive impairment commonly have airway obstruction (26–45%) and associated hypoxemia (15–55%).[8,12,129,130] These patients with severe cognitive impairment typically undergo emergency tracheal intubation.[27,30,44,69] In addition, patients with smoke inhalation are at risk for airway obstruction and commonly undergo emergency tracheal intubation.[131–143]

Scientific Evidence

Twenty-one studies of trauma patients undergoing emergency tracheal intubation provide evidence that patients with airway obstruction need tracheal intubation (Table 1).[14,16,22,23,31,32,38,41,50,57,65,74,81,109,111,113,115,116,119,144,145] (For tables, see EAST Web site: www.east.org/trauma practice guidelines/Emergency Tracheal Intubation Following Traumatic Injury.) The majority of the 6,486 patients in these studies underwent emergency tracheal intubation. However, the percentage of study patients with airway obstruction was often not available. In virtually all studies, airway obstruction was a protocol criterion for tracheal intubation. Because trauma center directors and EMS medical directors create protocol criteria and are knowledgeable in airway management, these experts indicate that intubation is essential. Also, some investigators, after study analysis, concluded that patients with airway obstruction should undergo tracheal intubation. Publication of these conclusions in a peer-reviewed journal implies editorial board endorsement. In summary, the intubation protocols and study conclusions indicate that trauma patients with airway obstruction need emergency tracheal intubation. Some investigators endorse emergency tracheal intubation for trauma

patients with severe neck injury by inclusion as an intubation protocol criterion or as a conclusion after analysis of a patient study.[57,80,113,114] An additional 11 study investigators endorse tracheal intubation for airway obstruction in patients with smoke inhalation.[134,135,137,139–143,146–148]

The American College of Surgeons, the National Association of Emergency Medical Technicians, and the National Association of EMS Physicians also advocate emergency tracheal intubation for airway obstruction in trauma patients.[149–151]

Level I Recommendation

Trauma patients with airway obstruction need emergency tracheal intubation.

B. Evidence that Trauma Patients with Hypoventilation Need Emergency Tracheal Intubation

Background

There is documentation that patients with cervical spinal cord injury often have hypoventilation.[152–155] The need for emergency tracheal intubation in these patients with cervical spine injury is 22% (range, 14–48%).[41,63,87–89]

There is also documentation that patients with severe cognitive impairment have abnormal breathing patterns and can have hypoventilation.[11,156–159] Severe cognitive impairment patients typically undergo emergency tracheal intubation.[27,30,44,69]

Scientific Evidence

Sixteen studies of trauma patients undergoing emergency tracheal intubation provide evidence that patients with hypoventilation need tracheal intubation (Table 2).[14,25,30–34,38,41,42,50,51,65,69,81,144] The majority of the 7,542 patients in these studies underwent emergency tracheal intubation. However, the percentage of study patients with hypoventilation was often not available. In all studies, hypoventilation was a protocol criterion for tracheal intubation.

The American College of Surgeons, the National Association of Emergency Medical Technicians, and the National Association of EMS Physicians also advocate emergency tracheal intubation for hypoventilation in trauma patients.[149–151]

Level I Recommendation

Trauma patients with hypoventilation need emergency tracheal intubation.

C. Evidence that Trauma Patients with Severe Hypoxemia Need Emergency Tracheal Intubation

Background

Severe hypoxemia is defined as persistent hypoxemia, despite the administration of supplemental oxygen. Hypoxemia may be secondary to airway obstruction, hypoventilation, lung injury, or aspiration. See evidence for airway obstruction and hypoventilation in the previous sections.

There is substantial documentation that patients with severe cognitive impairment (GCS score $\leq$ 8) commonly have hypoxia, which worsens neurologic outcome.[4–10,12,13,130,154,157,158,160–171] Severe cognitive impairment patients typically undergo emergency tracheal intubation to treat or prevent respiratory system insufficiency.[27,30,44,69]

There is also substantial documentation that blunt or penetrating thoracic injury can cause respiratory distress and hypoxemia.[171–177] Multiple studies document that emergency tracheal intubation is required for 40% to 60% of patients sustaining pulmonary contusion,[65,178–182] chest wall fractures,[54,183,184] or flail chest.[53,56,185–189]

Scientific Evidence

Eight studies of trauma patients undergoing emergency tracheal intubation provide evidence that patients with severe hypoxemia need tracheal intubation (Table 3).[25,48,50,65,73,75,81,183] The majority of the 4,090 patients in these studies underwent emergency tracheal intubation. However, the percentage of study patients with severe hypoxemia was often not available. In virtually all studies, severe hypoxemia was a protocol criterion for tracheal intubation. Also, some investigators, after study analysis, concluded that patients with severe hypoxemia should undergo tracheal intubation.

Sixteen studies of trauma patients undergoing emergency tracheal intubation provide evidence that patients with respiratory distress need tracheal intubation (Table 4).[25,33,38,48–50,57,58,65,73,74,89,109,113,119,144] The majority of the 3,218 patients in these studies underwent emergency tracheal intubation. However, the percentage of study patients with respiratory distress was often not available. In virtually all studies, respiratory distress was a protocol criterion for tracheal intubation. Also, some investigators, after study analysis, concluded that patients with respiratory distress should undergo tracheal intubation.

The American College of Surgeons, the National Association of Emergency Medical Technicians, and the National Association of EMS Physicians also advocate emergency tracheal intubation for severe hypoxemia in trauma patients.[149–151]

Level I Recommendation

Trauma patients with severe hypoxemia need emergency tracheal intubation.

D. Evidence that Trauma Patients with Severe Cognitive Impairment (GCS Score $\leq$ 8) Need Emergency Tracheal Intubation

Background

There is extensive literature to indicate that trauma patients with severe cognitive impairment (GCS score $\leq$ 8) commonly have airway obstruction, hypoventilation, and hypoxia.[4–13,129,130,154,156–163,165,168–171,190–197] Fourteen studies also demonstrate that respiratory system insufficiency worsens the neurologic outcome for postinjury severe cognitive impairment.[5,6,8–13,130,164,166,167,170,195]

Several studies indicate that severe cognitive impairment patients typically undergo emergency tracheal intubation.[27,30,44,69] However, EMS ground crews may intubate a much lower percentage of patients with severe cognitive impairment (33%) as opposed to patients managed by aeromedical crews (85%).[27,30,44,69] Other authors also recommend emergency tracheal intubation for patients with severe cognitive impairment secondary to smoke inhalation.[135,137,138,143,146]

Scientific Evidence

Three studies document the benefit of early tracheal intubation for patients with severe cognitive impairment. In a case-control study (data class II methodology), Winchell and Hoyt found a significant reduction in mortality with prehospital tracheal intubation.[30] Cooper and Boswell showed a decrease in injury-related complications and Hicks et al. demonstrated a reduction in hypoxemia during transfer to a trauma center.[161,198] The Winchell and Hoyt study evaluated the impact of prehospital intubation on mortality in blunt trauma patients with a GCS score $\leq$ 8. Paramedics were permitted to perform orotracheal intubation (OTI) without drug-assistance when hypoventilation was present. Of the patients with severe brain injury and extracranial trauma, the intubated and nonintubated patients had similar GCS scores, head/neck Abbreviated Injury Scale (AIS) scores, and ISSs. The mortality rate was significantly lower for the intubated patients (35.6%) when compared with those without intubation (57.4%; relative risk, 0.62; $p \ll 0.0001$). For the patients with isolated severe brain injury, the intubated and nonintubated patients had similar GCS scores, head/neck AIS scores, and ISSs. The mortality rate was significantly lower for the intubated patients (22.8%) when compared with those without intubation (49.6%; relative risk, 0.46; $p \ll 0.0001$).

Thirty-one studies of trauma patients undergoing emergency tracheal intubation provide evidence that patients with severe cognitive impairment (GCS score $\leq$ 8) need tracheal intubation (Table 5).[14,22,24–27,30,32–34,37,38,40,42,44,48–50,70,73–75,80,81,89,109,144,145,159,198,199] The majority of the 11,385 patients in these studies underwent emergency tracheal intubation. However, the percentage of study patients with severe cognitive impairment (GCS score $\leq$ 8) was often not available. In virtually all studies, severe cognitive impairment (GCS score $\leq$ 8) was a protocol criterion for tracheal intubation. Also, some investigators, after study analysis, concluded that patients with severe cognitive impairment (GCS score $\leq$ 8) should undergo tracheal intubation.

Thirteen investigators, who managed 2,586 trauma patients, also endorse emergency tracheal intubation for combativeness by inclusion as an intubation protocol criterion or as a conclusion after analysis of a patient study.[14,17,18,24,32,34,37,38,40,50,74,75,80] Some investigators endorse tracheal intubation for profuse vomiting by inclusion as an intubation protocol criterion or as a conclusion after analysis of a patient study.[14,70] Several American and European professional organizations and societies advocate emergency tracheal intubation for postinjury severe cognitive impairment (GCS score $\leq$ 8).[149,151,200–203]

Level I Recommendation

Trauma patients with severe cognitive impairment (GCS score $\leq$ 8) need emergency tracheal intubation.

E. Evidence that Trauma Patients with Cardiac Arrest Need Emergency Tracheal Intubation

Scientific Evidence

Ten studies of trauma patients undergoing emergency tracheal intubation provide evidence that patients with cardiac arrest need tracheal intubation (Table 6).[23,25,33,35,38,42,49,51,75,81] The majority of the 3,567 patients in these studies underwent emergency tracheal intubation. However, the percentage of study patients with cardiac arrest was often not available. In all studies, cardiac arrest was a protocol criterion for tracheal intubation. Also, some investigators, after study analysis, concluded that patients with cardiac arrest should undergo tracheal intubation. A study of 131 traumatic cardiac arrest patients showed that emergency tracheal intubation was associated with increased survival.[35]

The American College of Emergency Physicians and the National Association of EMS Physicians also endorse emergency tracheal intubation for traumatic cardiac arrest.[203] Although the European Resuscitation Council and American Heart Association recommend the laryngeal mask airway and Combitube as alternatives for airway management during cardiac arrest, an endotracheal tube is preferred.[204,205]

Level I Recommendation

Trauma patients in cardiac arrest need emergency tracheal intubation.

F. Evidence that Trauma Patients with Severe Hemorrhagic Shock Need Emergency Tracheal Intubation

Scientific Evidence

Ten studies of trauma patients undergoing emergency tracheal intubation provide evidence that patients with severe hemorrhagic shock need tracheal intubation (Table 7).[22,24,25,50,65,74,81,89,145,183] The majority of the 5,633 patients in these studies underwent emergency tracheal intubation. However, the percentage of study patients with severe hemorrhagic shock was often not available. In virtually all studies, severe hemorrhagic shock was a protocol criterion for tracheal intubation. Also, some investigators, after study analysis, concluded that patients with severe hemorrhagic shock should undergo tracheal intubation.

Eleven studies have described 3,032 hemodynamically unstable patients with blunt or penetrating torso trauma in need of emergency celiotomy or thoracotomy.[206–216] The American College of Surgeons advocates emergency tracheal

intubation for emergency surgery, because neuromuscular paralysis is needed.[149]

Level I Recommendation

Emergency tracheal intubation is needed for severe hemorrhagic shock in trauma patients and is essential when emergency thoracotomy or celiotomy is required.

G. Evidence that Select Patients with Smoke Inhalation Need Emergency Tracheal Intubation

Background

After smoke inhalation, acute respiratory system insufficiency can be caused by carbon monoxide toxicity and thermal or combustion-product tissue injury. Carbon monoxide can create central nervous system hypoxia and tissue injury can lead to supraglottic, glottic, or infraglottic airway obstruction. Typical acute manifestations of smoke inhalation are airway obstruction, hypoventilation, and severe cognitive impairment. Although severe hypoxemia ($\downarrow$ Pao_2) is not typical, it can occur if there has been pulmonary aspiration or traumatic lung contusion.

Tracheal intubation is needed at some time in 16.6% (range, 4–27%) of burn patients.[146,148,217–219] The incidence of smoke inhalation injury for patients who have burn injury is 10.7% (range, 3–60%).[134,135,140,147,220–225] Clinical indicators of smoke inhalation include the following:

- closed-space injury[132-134,139-141,143,147,148,221,223,225]
- facial burns[132–135,137,140,141,143,147,148,221,223–226]
- singed nasal vibrissae[139,141,148,221,225]
- soot in oropharynx[138,139,146,225]
- oropharyngeal burns[134,141,143,146,148,221,225]
- hoarseness[132,134,137,140-143,221,225]
- airway obstruction[221]
- wheezing[134,138–142]
- carbonaceous sputum[133,134,140-143,148,221,225]
- unconsciousness[135,148]

Multiple investigators describe endoscopy in 1,325 patients with heat-related injury and advocate its use for quantifying the smoke inhalation injury.[133,135–137,139–141,143,148,223–225,227] During endoscopy, the upper airway disease was found to be highly variable (none, mild, moderate, and severe).

Scientific Evidence

Some authors advocate routine tracheal intubation for smoke inhalation as a protocol recommendation or study conclusion.[136,142,221] However, a much greater number of investigators endorse selective tracheal intubation.[134,135,137–143,146–148,224,225]

Numerous authors recommend tracheal intubation for airway obstruction that is clinically present or when severe edema is seen on endoscopy.[134,135,137,139–143,146–148,225] Several investigators advocate tracheal intubation for unconscious smoke inhalation patients.[135,137,138,143,146] A few authors endorse tracheal intubation for patients who have bronchospasm,[134] respiratory distress,[135] full-thickness facial burns,[135,146] circumferential neck burns,[135] oropharyngeal burns,[135,146] oropharyngeal soot,[138] hoarseness,[138] or carbonaceous sputum.[142,146]

Investigators have described 16 groups of smoke inhalation patients who needed tracheal intubation.[131–143,224] The overall rate of emergency tracheal intubation was 62.2% (605 of 972). Six groups of patients with smoke inhalation and cutaneous burns (40–55%) revealed an overall intubation rate of 77.5% (502 of 648; 95% confidence interval [CI], 74.3–80.7%),[131–135,224] whereas five groups of patients with isolated smoke inhalation had an overall intubation rate of 41.7% (65 of 156; 95% CI, 34.0–49.4%).[131,135–138] The relative risk for tracheal intubation was 1.9 for the patients with cutaneous burns when compared with the patients without burns ($p \ll 0.001$). In another five groups of mixed smoke inhalation patients where some patients in each study had cutaneous burns and others did not, the tracheal intubation rate was 22.6% (38 of 168; 95% CI, 16.3–28.9%).[139–143] The rate of tracheal intubation in these mixed patients was much lower when compared with the 77.5% rate in the studies where all patients had cutaneous burns ($p \ll 0.001$).

One study described four patients who developed delayed airway obstruction and required tracheal intubation 4 to 10 hours postinjury.[142] However, it is unclear whether these patients had cutaneous burns.

Haponik et al. studied 36 patients who had cutaneous burns and/or clinical indications of smoke inhalation.[143] Patients requiring emergency intubation were excluded (airway obstruction, hypoventilation, severe hypoxemia). Initial fiberoptic nasopharyngoscopy revealed mild inflammation in 29 patients (80.6%) and moderate to severe inflammation in 7 patients (19.4%). Repeat fiberoptic nasopharyngoscopy revealed a stable airway in 22 (61.1%) and progressive airway edema in 14 (38.9%). Six patients required subsequent tracheal intubation for airway obstruction (16.7% of total group and 42.9% of group with progressive edema). The 14 patients with progressive airway edema had larger cutaneous burns (27.8% vs. 8.0%; $p < 0.0001$) and a higher rate of facial/neck cutaneous burns (92.9% vs. 59.1%; $p < 0.05$). These data further indicate the increased need for tracheal intubation in smoke inhalation patients with major cutaneous burns.

The American College of Surgeons Committee on Trauma lists the following as indicators of smoke inhalation injury: facial burns, singeing of the eyebrows and nasal vibrissae, carbon deposits and acute inflammatory changes in the oropharynx, carbonaceous sputum, history of impaired mentation and/or confinement in a burning environment, explosion with burns to head and torso, and carboxyhemoglobin level greater than 10% if the patient is involved in a fire.[149] The College endorses tracheal intubation in smoke inhalation patients with a prolonged transport time or stridor.

The National Association of Emergency Medical Technicians recommends intubation when the potential for losing the airway exists because of progressive edema.[150] The American College of Emergency Physicians and the National Association of EMS Physicians advocate tracheal intubation

for (1) patients requiring secondary transport to a burn center and receiving large-volume fluid infusion, (2) stridor, or (3) unconsciousness.[203]

Level I Recommendation

Smoke inhalation patients with the following conditions need emergency tracheal intubation:

1. airway obstruction
2. severe cognitive impairment (GCS score $\leq$ 8)
3. a major cutaneous burn ($\geq$40%)
4. impending airway obstruction:
   a) moderate to severe facial burn
   b) moderate to severe oropharyngeal burn
   c) moderate to severe airway injury seen on endoscopy
5. a prolonged transport time

VI. RECOMMENDATIONS FOR PROCEDURAL OPTIONS IN TRAUMA PATIENTS UNDERGOING EMERGENCY TRACHEAL INTUBATION

Level I

Level I recommendations are typically predicated on evidence from randomized, controlled trials. The relevant literature is devoid of randomized, controlled trials and has been comprehensively reviewed to find the best available evidence. The recommendations are based on several peer-reviewed journal publications from institutions throughout the United States and are typically supported in multiple professional organization and society publications. The committee did not find alternative management strategies that were as effective as the recommendations. In summary, the committee consensus finds the recommendations to reflect management principles with a high degree of certainty.

1. Orotracheal intubation guided by direct laryngoscopy is the emergency tracheal intubation procedure of choice for trauma patients.

2. When the patient's jaws are not flaccid and OTI is needed, a drug regimen should be given to achieve the following clinical objectives:
   a) neuromuscular paralysis
   b) sedation, as needed
   c) maintain hemodynamic stability
   d) prevent intracranial hypertension
   e) prevent vomiting
   f) prevent intraocular content extrusion

3. Enhancements for safe and effective emergency tracheal intubation in trauma patients include:
   a) availability of experienced personnel
   b) pulse oximetry monitoring
   c) maintenance of cervical spine neutrality
   d) application of cricoid pressure
   e) carbon dioxide monitoring

4. Cricothyrostomy is appropriate when emergency tracheal intubation is needed and the vocal cords cannot be visualized during laryngoscopy or the pharynx is obscured by copious amounts of blood or vomitus.

Level III

The laryngeal mask airway and Combitube are alternatives to cricothyrostomy and may be selected when cricothyrostomy expertise is limited.

VII. SCIENTIFIC FOUNDATION FOR PROCEDURAL OPTIONS IN TRAUMA PATIENTS UNDERGOING EMERGENCY TRACHEAL INTUBATION

A. Evidence for Emergency Tracheal Intubation in Trauma Patients

Scientific Evidence for Emergency Orotracheal Intubation in Trauma Patients

Multiple authors have published their experience with emergency OTI in 12,045 trauma patients. There were 955 trauma patients who had OTI without drug-assistance in aeromedical, ground EMS, and trauma center settings.[20,26,30,33,36,40,42,45,73,228] There were 5,692 trauma patients who had OTI with drug-assistance in aeromedical, ground EMS, emergency department, and trauma center settings.[14,17,18,22,26,30, 32,34, 38,44,48,50,64,74,80,88,111,115,144,229–236] Additional studies describe the details of trauma patients who had emergency OTI where some received drugs assistance (1,967) and others did not (544).[14,19,24,26,37,39,40,45,48,49,68,73,75,228,237] In another 2,887 patients who had OTI, some received drug-assistance and others did not.[19,21,23,27,38,42,57,63,78,81,89,109,113,116,118,119,145, 198,228,238,239] However, the number of patients receiving drugs was not stated in the publications.

The overall failure-to-intubate rate for OTI without drug-assistance was 20.8% (Table 8): EMS ground crew studies, 33.5%;[33,42] aeromedical crews, 18.4%;[26,36,37,48,228] and emergency department (ED)/trauma center (TC) staff, 11.4%.[40,68,237] The intubation failure rate for OTI without drug-assistance was higher for EMS ground crews when compared with aeromedical crews or TC/ED settings. The GCS scores for patients who had OTI without drug-assistance was 3 or 4.[26,40,42] The OTI success rate was greater for the patients with a GCS score of 3 when compared with the patients with a GCS score of 4 ($p = 0.04$). These data suggest that OTI without drug-assistance is only appropriate for patients with negligible neurologic function. The overall complication rate for OTI without drug-assistance was calculated to be 19.0% (Table 9).[14,26,39,68] However, the true incidence is uncertain.

The overall intubation success rate for OTI with drug-assistance was 96.3% (5,745 of 5,963) (Table 10): 96.9% in 3,213 patients managed by aeromedical crews,[22,26,32,34,37, 38,44,48,50,73,74,144,228] 98.2% in 563 patients managed by ED staff,[230,237] 92.4% in 1,244 patients managed by ground EMS crews,[231,232,240] and 98.3% in 943 patients managed by TC staff.[14,18,34,40,49,64,68,80,111,115,233,234,236,241] The GCS score, when available, was between 6 and 12 in most patients.[26,34,37,38,48–50]

This literature indicates that there is a substantial experience with emergency drug-assisted OTI in trauma patients in multiple settings and that the intubation success rate ap-

proaches but does not reach 100%. However, there are only a few published studies that describe ground EMS crew experience with drug-assisted OTI in trauma patients.[231,232,240]

There is one large ground EMS study where a 94.1% success rate (1,044 of 1,110) for OTI with drug-assistance in trauma patients was described.[232] Factors that were likely to have been associated with this success included well-trained paramedics, a strategy for skills maintenance, rigorous medical control, an active quality assurance (QA) process, and the use of tracheal intubation confirmation by carbon dioxide detectors and/or tube aspiration devices.

There is a recent prospective, ground EMS study where 117 patients with traumatic brain injury (GCS score $\leq$ 8) were managed with rapid-sequence intubation.[240] The overall intubation success rate was 99.1%: 99 with drug-assisted OTI and 17 with esophagotracheal Combitube placement. The drug-assisted OTI success rate was 84.6% (99 of 117). Of the 18 patients with unsuccessful OTI, 17 (94.4%) were managed with an esophagotracheal Combitube. The preintubation Spo_2 for the 117 patients was 89% and the postintubation Spo_2 was 98%.

The overall complication rate for OTI with drug-assistance was calculated to be 3.6% (138 of 3,886) for aeromedical, ground EMS, emergency department, and trauma center settings (Table 11).[14,18,26,32,34,39,44,48,68,73,74,88,111,144,228–230,232–234,242] The literature suggests that the complication rate for drug-assisted OTI is relatively low; however, the true incidence is unclear.

Twenty-two studies report that the typical indication for drug-assisted OTI is jaw rigidity.[14,17,18,26,30,32,37,38,40,42,44,49,68,73,80,81,88,229–233] Thirty-two reports document that a drug regimen used to enhance OTI success should consider the need for patient sedation.[14,17–19,24,26,32,34,37,38,40,45,48–50,64,73,74,80,81,88,89,115,144,228,229,231–233,235–237] Thirty-eight studies indicate that a drug regimen used to enhance OTI success should include patient-induced paralysis.[14,17–19,22,24,26,30,32,34,37–40,42,44,45,48–50,64,68,73,75,80,81,88,89,115,144,228–233,236,237] There is also endorsement for patient-induced paralysis during OTI by the National Association of Emergency Medical Technicians, the Italian Societies of Neurosurgery and Anesthesia and Critical Care, and the National Association of EMS Physicians.[150,151,202]

Twenty-two reports indicate that a drug regimen used to enhance OTI success should include the need to prevent intracranial hypertension, in general,[14,17,18,26,32,37,38,40,44,45,50,73,81,144,228–233,236,237] and Lidocaine, in particular.[19,24,26,32,34,37,40,44,45,48–50,73,81,228,232,233,237] There is also endorsement for Lidocaine administration during tracheal intubation by the American College of Emergency Physicians and the National Association of EMS Physicians.[203]

Fourteen investigators indicate that a drug regimen used to enhance OTI success should include the need to prevent hemodynamic instability.[14,19,24,32,38,40,49,81,144,229–231,235,236] Multiple authors indicate that a drug regimen used to enhance OTI success should include the need to prevent vomiting[14,19,24,26,32,37,38,40,80,229,230,233,236] and the extrusion of intraocular contents.[18,24,37,40,81,233]

Nine investigators have described OTI in 285 patients with cervical spine injury without neurologic deterioration.[14,18,21,39,63,88,89,234,239] This literature indicates that OTI is relatively safe for patients with cervical spine injury.

Scientific Evidence for Emergency Nasotracheal Intubation in Trauma Patients

Emergency nasotracheal intubation (NTI) data have been described for trauma patients by multiple investigators and provide intubation success rates for 620 patients and complication rates for 573 patients. The overall intubation success rate was 76.8% (476 of 620): aeromedical crews, 78.3%; emergency department staff, 71.4%; ground EMS crews, 69.7%; and trauma center staff, 64.3% (Table 12).[26,36,38,40,44,50,64,78,109,237,243] This was an overall 23.2% intubation failure rate for emergency NTI in trauma patients. Two studies with a total of 380 patients reported a GCS score of 6 and 7 for patients undergoing emergency NTI.[26,36] These findings indicate that the patients had severe cognitive impairment and were probably spontaneously breathing. These GCS values were higher than those for patients undergoing OTI without drug-assistance and similar to those with drug-assistance.

ED versus field NTI. The success rate is $<$ 80% for NTI in the emergency department and in the prehospital environment. However, the reported experience in the EMS ground and ED settings is small. The data suggest that NTI is likely to fail in a significant percentage of trauma patients managed by EMS ground crews.

The overall complication rate for emergency NTI in trauma patients was calculated to be 4.4% and included data for aeromedical, EMS ground, emergency department, and trauma center settings (Table 13).[14,18,21,26,36,39,44,89,109,128,239] However, an accurate incidence is uncertain. Principal indications for emergency NTI in trauma patients were jaw rigidity and cervical spine injury.[18,26,36,41,44,87,239,243]

Scientific Evidence for Emergency Fiberoptic Tracheal Intubation in Trauma Patients

During the past 22 years, attempts at emergency tracheal intubation with fiberoptic assistance have been described in 42 trauma patients (Table 14).[58,64,68,118,244–246] Tracheal intubation was successful in 35 (83.3%; 95% CI, 72.0–94.6%). Indications for emergency fiberoptic-assisted tracheal intubation were rigid jaws,[244] cervical spine injury,[244,245] laryngotracheal injury,[58,64,68,118] and obscured pharynx from blood or vomitus.[244–246]

Scientific Evidence Comparing Emergency Tracheal Intubation Procedures in Trauma Patients

Of the 44 trauma patient studies where OTI and non-OTI procedures were performed, OTI was the most common method for emergency tracheal intubation (Table 15).[14,18,

22–24,26,27,30,32,36–40,44,45,49,50,57,64,68,73–75,78,80,81,88,89,109,113,115,116,118,119,144,145,228,230,232,235,237,239 These studies provided the intubation procedure for 11,408 patients: OTI, 9,738 (85.4%); NTI, 1,404 (12.3%); cricothyrostomy, 196 (1.7%); and tracheostomy, 70 (0.6%). Although OTI was still the most common procedure in 342 patients with severe neck injury (70.5%), the emergency tracheostomy rate increased to 19.9%.[57,64,68,109,113,115,116,118,119]

Emergency intubation procedure success rates in EMS ground, aeromedical, emergency department, and trauma center settings were OTI without drug-assistance, 79.2% (471 of 595); OTI with drug-assistance, 96.3% (5,745 of 5,963); NTI, 76.8% (476 of 620); and cricothyrostomy, 95.7% (421 of 440) (Table 16). Specific studies are cited in previous sections. Emergency intubation failure rates were OTI without drug-assistance, 20.8% (95% CI, 17.5–24.1%); OTI with drug-assistance, 3.7% (95% CI, 3.2–4.2%); NTI, 23.2% (95% CI, 19.9–26.5%); and cricothyrostomy, 4.3% (95% CI, 2.4–6.2%). The relative risk of intubation failure for OTI without drug-assistance was 6.1 when compared with OTI with drug-assistance ($p \ll 0.001$). The overall intubation failure rate for OTI without drug-assistance by EMS ground crews was 33.5% (95% CI, 26.3–40.7%).[33,42] The relative risk of intubation failure for NTI was 6.8 when compared with OTI with drug-assistance ($p \ll 0.001$).

There was limited literature relative to ground EMS crew success rates for OTI with drug-assistance in trauma patients. However, one large ground EMS study reported a 94.1% success rate (1,044 of 1,110).[232] It is important to recognize that multiple factors were likely to have been associated with this intubation success: well-trained paramedics, a strategy for skills maintenance, rigorous medical control, an active QA process, and the use of tracheal intubation confirmation by carbon dioxide detectors and/or tube aspiration devices.

Overall emergency intubation complication rates were OTI without drug-assistance, 19.0% (95% CI, 13.7–24.3%); OTI with drug-assistance, 3.6% (95% CI, 3.0–4.2%); NTI, 4.4% (95% CI, <2.7–6.1%); and cricothyrostomy, 9.6% (95% CI, 7.1–12.1%) (Table 17). Specific studies are cited in previous sections. There were no reports that described EMS ground crew complication rates for OTI without drug-assistance or NTI procedures.

Three aeromedical studies documented an increase in tracheal intubation success rates in trauma patients when drug-assisted OTI was available (Table 18).[37,73,228] Although Falcone et al. showed no improvement in overall intubation success in tracheal intubation without (97%) and with (100%) drug-assistance, there were fewer NTI procedures and a similar cricothyrostomy rate in the latter group.[45]

Multiple studies document an overall emergency intubation success rate approaching 100% when multiple procedural options are used. Seventeen aeromedical studies with 21 trauma patient groups documented an overall emergency tracheal intubation success of 97.3% (4,858 of 4,989) (Table 19).[22,23,26,27,32,36,38,44,45,48,50,72–75,144,228] Of the 21 patient groups, 16 (77%) reported an overall success rate ≥ 95% when multiple intubation procedures were available. Of five studies with an overall intubation success rate < 95%, either drug-assisted intubation was not used,[73,228] may not have been used,[27,72] or was used, but the percentage of patients receiving drugs was not stipulated.[38]

The overall emergency intubation success rate in trauma patients was 100% (n = 684) in three emergency department studies when multiple procedural options were available (Table 20).[109,230,237] All studies described the availability of drug-assisted OTI, as needed.

When multiple procedural techniques were available, the overall emergency intubation success rate in trauma patients was 96.7% (2,134 of 2,201) in three EMS ground crew studies (Table 21).[28,78,232] In the one study with an intubation success of 89%, NTI was the most frequent procedure used.[78]

A recent EMS ground crew, prospective study describes the intubation success rate in patients with severe traumatic brain injury (GCS score ≤ 8).[240] Patients were managed with rapid-sequence drug-assistance and had an overall intubation success rate of 99.1% (116 of 117). Of those successfully intubated, 99 had OTI (85.3%) and 17 were managed by esophagotracheal Combitube placement (14.7%). The preintubation Spo_2 was 89% for the entire group and the postintubation Spo_2 was 98%.

Twenty trauma center studies have described 23 patient groups where the overall emergency intubation success rate was 99.9% (3,398 of 3,401) (Table 22).[18,19,24,39,40,49,57,58,64,67,68,80,81,88,113,118,119,145,239] Multiple procedural options were used in all but one patient group.[19]

Several studies indicate that a substantial percentage of trauma patients in need of emergency tracheal intubation have the procedure delayed until trauma center arrival. Six studies describe 1,032 patients that were intubated prehospital or on trauma center arrival (Table 23).[20,33,42,46,82,128] Only 27.4% were intubated before trauma center arrival: 52% in the aeromedical crew studies and 26% in the EMS ground crew studies.

Five studies describe the timing of tracheal intubation in six patient groups (n = 2,982) with severe traumatic brain injury (GCS score ≤ 8) (Table 24).[27,30,30,44,69] Prehospital intubation was lower in the patients managed by EMS ground crews (33.4% [649 of 1,944]) when compared with those treated by aeromedical crews (85.1% [883 of 1,038]).

Scientific Evidence for Enhancements during Emergency Tracheal Intubation in Trauma Patients

Maintenance of cervical spine neutrality. Nineteen studies of trauma patients undergoing emergency tracheal intubation provide evidence that cervical spine neutrality should be maintained during tracheal intubation.[14,18,20,22–24,37–39,49,63,81,87–89,229,233,237,238] The majority of the 7,927 patients in these studies underwent emergency tracheal intubation. Some of the studies described the maintenance of cervical spine neutrality as a

protocol procedural objective. In some studies, the authors concluded that patients undergoing emergency tracheal intubation should have cervical spine neutrality maintained.

The National Association of Emergency Medical Technicians, the American College of Emergency Physicians, the National Association of EMS Physicians, the Italian Societies of Neurosurgery and Anesthesia and Intensive Care, and the American College of Surgeons Committee on Trauma endorse maintaining cervical spine neutrality during the emergency tracheal intubation of trauma patients.[149,150,202,203]

Availability of experienced personnel Thirty-seven studies of trauma patients undergoing emergency tracheal intubation provide evidence that experience and training are important for safe and effective intubation.[14–16,18,19,23,26,29,31,32,34,38,40,42,43,48,50,51,60,61,63,73–75,78,80,81,88,116,128,144,229,232,237,243,244,247] The majority of the 7,465 patients in these studies underwent emergency tracheal intubation. Some of the authors concluded in their studies that emergency tracheal intubation should be performed by experienced and well-trained personnel. Some authors described the extensive training and experience of the personnel in the Materials and Methods section of the article. Training and experience requirements are typically determined by trauma center directors and EMS medical directors who are expert in airway management.

The National Association for EMS Physicians has recently published a position paper that endorses prehospital rapid-sequence intubation in select patients.[151] This article also emphasizes the importance of adequate training, clinical experience, and QA programs to ensure tracheal intubation success.

Carbon dioxide monitoring. Seven studies of trauma patients undergoing emergency tracheal intubation provide evidence that carbon dioxide monitoring should be used to document successful tube placement.[19,32,48,68,229,232,237] The majority of the 2,578 patients in these studies underwent emergency tracheal intubation. In virtually all studies, carbon dioxide monitoring was a routine protocol procedure. Some investigators, after study analysis, concluded that patients should have routine carbon dioxide monitoring during emergency tracheal intubation.

Carbon dioxide monitoring is recommended for emergency tracheal intubation in trauma patients by multiple professional organizations. These groups include the National Association of Emergency Medical Technicians, the American College of Emergency Physicians, the National Association of EMS Physicians, the Italian Societies of Neurosurgery and Anesthesia and Intensive Care, the American College of Surgeons Committee on Trauma, the American College of Emergency Physicians, and the National Association of EMS Physicians.[149,150,202,203,248] The American College of Surgeons Committee on Trauma requires a capnography device for Level I to IV trauma center verification.[249]

Application of cricoid pressure. Twenty-one studies of trauma patients undergoing emergency tracheal intubation provide evidence that application of cricoid pressure should be a routine procedure.[14,18,20,26, 32,34,37,38,45,48,73,80,81,88,144,228–230,233,237,238] The majority of the 7,886 patients in these studies underwent emergency tracheal intubation. In virtually all studies, cricoid pressure was a routine protocol procedure during tracheal intubation. Some investigators, after study analysis, concluded that cricoid pressure should be applied to patients undergoing tracheal intubation.

The American College of Emergency Physicians, the National Association of EMS Physicians, and the Italian Societies of Neurosurgery and Anesthesia and Intensive Care recommend the application of cricoid pressure during emergency tracheal intubation in trauma patients.[202,203]

Pulse oximetry monitoring. Pulse oximetry monitoring is recommended for emergency tracheal intubation in trauma patients by several professional societies and organizations: the National Association of Emergency Medical Technicians,[150] the Italian Societies of Neurosurgery and Anesthesia and Intensive Care,[202] the American College of Surgeons Committee on Trauma,[149] the Brain Trauma Foundation and American Association of Neurologic Surgeons,[200,201] and the American College of Emergency Physicians and the National Association of EMS Physicians.[203,248]

Level I Recommendations

Orotracheal intubation guided by direct laryngoscopy is the emergency tracheal intubation procedure of choice for trauma patients. When the patient's jaws are not flaccid and OTI is needed, a drug regimen should be given to achieve the following clinical objectives:

- neuromuscular paralysis
- sedation, as needed
- maintain hemodynamic stability
- prevent intracranial hypertension
- prevent vomiting
- prevent intraocular content extrusion

Enhancements for safe and effective emergency tracheal intubation in trauma patients include the following

- availability of experienced personnel
- pulse oximetry monitoring
- maintenance of cervical spine neutrality
- application of cricoid pressure
- carbon dioxide monitoring

B. Evidence for Emergency Cricothyrostomy and Tracheostomy in Trauma Patients

Scientific Evidence for Emergency Cricothyrostomy in Trauma Patients

Thirteen investigators have described an experience with emergency cricothyrostomy for trauma patients in aeromedical, ground EMS, emergency department, and trauma center settings (n = 653).[15,16,22,23,28,29,47,55,59–61,67,250] According to these studies, the patients were critically injured: ISS, 39.8 (data from 6 studies); GCS score, 3 to 4 (data from 3 studies);

and mortality, 68.8% (data from 12 studies). Cardiac arrest was present in 38.8% (data from 11 studies).

Studies in aeromedical and ground EMS settings have described an overall emergency cricothyrostomy intubation success rate of 95.8% (407 of 425) in trauma patients (Table 25).[15,16,22,23,28,29,37,47,50,60,61,67,74,144] The overall complication rate for emergency cricothyrostomy was 9.6% (51 of 530), with a range of 0% to 32% (Table 26).[14–16,21–23,28,29,39,47,55,59–61,67,74,88,144,145,237]

Field versus ED cricothyrostomy. The 93.5% success rate for ground EMS crews is close to the 98.1% rate for aeromedical crews (Table 16). The success rate in the TC/ED was 93.3%, but included only 15 patients. Complication rates were greater in the ED when compared with ground EMS and aeromedical crews (Table 26). The data suggest that EMS ground crew cricothyrostomy may be appropriate for select trauma patients. Of the studies with indications for emergency cricothyrostomy in trauma patients, reasons included nonvisualized vocal cords in 25 reports and obscured pharynx from blood or vomitus in 20 articles.[15,16,18,22,23,26,28,29,32,36,37,39,44,47,55,59–61,67,74,80,81,88,115,144,230,250]

Fiberoptic tracheal intubation versus emergency department cricothyrostomy. Fiberoptic tracheal intubation and cricothyrostomy may be indicated in the emergency department when the vocal cords cannot be visualized. The fiberoptic intubation success rate for the 42 patients described in the literature was 83.3%. However, a reliable rate for emergency department cricothyrostomy success is not available. The literature describes only 1 complication for the 25 patients undergoing emergency fiberoptic intubation. In contrast, the complication was 28.7% in the 122 patients undergoing emergency department cricothyrostomy. Future trauma patient investigations are necessary to delineate the precise roles for fiberoptic intubation and cricothyrostomy in the emergency department.

Scientific Evidence for Emergency Tracheostomy in Trauma Patients

Sixteen studies have described the performance of emergency tracheostomy in 135 trauma patients (Table 27).[40,57,58,64,67,68,109,113–120,251] Of these 135 patients, 130 had severe neck injuries. These studies described the management of 475 patients and indicated that the primary reason for emergency tracheostomy was laryngotracheal injury.

Level I Recommendation

Cricothyrostomy is appropriate when emergency tracheal intubation is needed and the vocal cords cannot be visualized during laryngoscopy or the pharynx is obscured by copious amounts of blood or vomitus.

C. Evidence for Emergency Combitube and Laryngeal Mask Airway in Trauma Patients

Scientific Evidence for Emergency Combitube in Trauma Patients

Emergency Combitube placement has been described in 53 trauma patients (Table 28).[31,51,232,240,252,253] The distribution of patients by setting was ground EMS, 42; aeromedical, 10; and emergency department, 1.

The success rate for Combitube placement was available in five studies and was calculated to be 90.9% (40 of 44; 95% CI, 82.4–99.4%). Patients undergoing emergency Combitube placement typically had a GCS score of 3 after rapid-sequence drug administration with failed OTI or cardiac arrest.[31,51,240,252]

There were no complications in the 26 trauma patients where such information was documented.[31,51,252,253] Indications for emergency Combitube placement in trauma patients were obscured pharynx from blood or vomitus and nonvisualized vocal cords.[31,51,240,252,253]

Scientific Evidence for Emergency Laryngeal Mask Airway in Trauma Patients

The emergency placement of a laryngeal mask airway (LMA) has been described in five trauma patients (Table 29).[241,254–256] The distribution of patients by setting was EMS ground, two; emergency department, one; and trauma center, two. Patients undergoing emergency LMA placement typically had a GCS score of 3 after rapid-sequence drug administration with failed OTI. There were no complications from LMA placement in the five patients.

The emergency placement of an intubating LMA was described in three trauma patients (Table 30).[257,258] All devices were placed in a trauma center environment. Patients undergoing emergency intubating LMA placement typically had a GCS score of 3 after rapid-sequence drug administration with failed OTI. There were no complications from intubating LMA placement in the three patients. The indication for emergency intubating LMA placement was failed drug-assisted OTI secondary to nonvisualized vocal cords, obscured pharynx from blood or vomitus, and cervical spine injury.[241,254–258]

Scientific Evidence for Emergency Combitube and Laryngeal Mask Airway in Critically Ill Patients

According to the literature, most trauma patients undergoing emergency Combitube or LMA placement have a GCS score of 3 after rapid-sequence drug administration and failed OTI or cardiac arrest. The published data describing emergency Combitube and LMA placement in trauma patients is limited. The European Resuscitation Council and the American Heart Association recommend the Combitube and LMA as alternatives to endotracheal intubation in cardiac arrest.[204,205] The American College of Emergency Physicians and the National Association of EMS Physicians recommend

the Combitube and LMA for endotracheal intubation failure in trauma patients.[203]

The National Association of Emergency Medical Technicians considers LMA and esophageal tracheal double-lumen airways as alternative airways to endotracheal intubation.[150] The association considers these devices as a short-term airway until endotracheal or surgical airway access can be obtained. An LMA is recommended when endotracheal intubation attempts are unsuccessful or as a back-up for failed rapid-sequence intubation. The American Society of Anesthesiologists, in their difficult airway algorithm, recommends the Combitube and LMA when there is endotracheal intubation failure and the inability to ventilate with a bag-valve mask.[259]

In a contemporary editorial, the Combitube and LMA are endorsed for endotracheal intubation failure in the emergency setting.[260] A recommendation for LMA insertion after endotracheal intubation failure and a detailed technical description has been recently published in the anesthesiology literature.[261]

Level III Recommendation

The laryngeal mask airway and Combitube are alternatives to cricothyrostomy and may be selected when cricothyrostomy expertise is limited.

VIII. TRAITS OF TRACHEAL INTUBATION STUDIES

Data Classification of Studies

The majority of cited tracheal intubation studies were data class III. However, the following studies were data class II: Baxt and Moody, 1987;[72] Broos et al., 1993;[62] Gentleman, 1992;[199] Gerich et al., 1998;[74] Jacobs et al., 1984;[77] Koenig, 1992;[233] Lee and Leung, 1992;[225] Levy et al., 1997;[113] Masanes et al., 1994;[227] McBrien et al., 1992;[19] Muehlberger et al., 1988;[137] Ochs et al., 2000;[51] Plewa et al., 1997;[236] Redan et al., 1991;[18] Rhee and O'Malley, 1994;[44] Sakles et al., 1998;[237] Shackford et al., 1981;[188] Sharma et al., 1996;[182] Shatney et al., 1995;[89] Syverud et al., 1988;[37] Tayal et al., 1999;[229] Thomas et al., 1999;[50] Trupka et al., 1994;[25] Vicario et al., 1983;[159] and Winchell and Hoyt, 1997.[30] There were no data class I studies cited.

Percentage of Trauma Patients

The majority of the cited tracheal intubation studies describe patients with a trauma mechanism. A trauma mechanism existed in 50% to 89% of the patients in the following studies: Boyle et al., 1993;[61] Erlandson et al., 1989;[59] Ma et al., 1998;[228] McGill et al., 1982;[55] Rose et al., 1994;[73] Sakles et al., 1998;[237] Slater et al., 1998;[48] Syverud et al., 1988;[37] Tayal et al., 1999;[229] Thomas et al., 1999;[50] and Thompson et al., 1982.[230] Intubation studies were not cited when less than 50% of the patients had a trauma mechanism.

IX. SUMMARY

A. Trauma Patients in Need of Emergency Tracheal Intubation

Emergency tracheal intubation is needed in trauma patients with the following traits: airway obstruction, hypoventilation, severe hypoxemia (hypoxemia despite supplemental oxygen), severe cognitive impairment (GCS score $\leq$ 8), cardiac arrest, and severe hemorrhagic shock.

Emergency tracheal intubation is needed in smoke inhalation patients with the following conditions: airway obstruction, severe cognitive impairment (GCS score $\leq$ 8), major cutaneous burn ($\geq$40%), prolonged transport time, and impending airway obstruction (moderate to severe facial burn, moderate to severe oropharyngeal burn, or moderate to severe airway injury seen on endoscopy).

B. Optimal Procedures for Trauma Patients Undergoing Emergency Tracheal Intubation

Orotracheal intubation guided by direct laryngoscopy is the emergency tracheal intubation procedure of choice for trauma patients. When the patient's jaws are not flaccid and OTI is needed, a drug regimen should be given to achieve the following clinical objectives: neuromuscular paralysis; sedation, as needed; maintain hemodynamic stability; prevent intracranial hypertension; prevent vomiting; and prevent intraocular content extrusion.

Cricothyrostomy is appropriate when emergency tracheal intubation is needed and the vocal cords cannot be visualized during laryngoscopy or the pharynx is obscured by copious amounts of blood or vomitus. The laryngeal mask airway and Combitube are alternatives to cricothyrostomy and may be selected when cricothyrostomy expertise is limited. Enhancements for safe and effective emergency tracheal intubation in trauma patients include availability of experienced personnel, pulse oximetry monitoring, maintenance of cervical spine neutrality, application of cricoid pressure, and carbon dioxide monitoring.

C. Procedural Options Algorithm for Trauma Patients in Need of Emergency Tracheal Intubation

See Figure 1.

- OTI guided by direct laryngoscopy is the recommended procedure for most trauma patients in need of emergency tracheal intubation.
- If the patient's jaws are not flaccid, administer a drug regimen to induce jaw flaccidity.
- The drug regimen is given to produce the following clinical objectives:
  1. neuromuscular paralysis
  2. sedation, as needed
  3. maintain hemodynamic stability
  4. prevent intracranial hypertension
  5. prevent vomiting
  6. prevent intraocular content extrusion

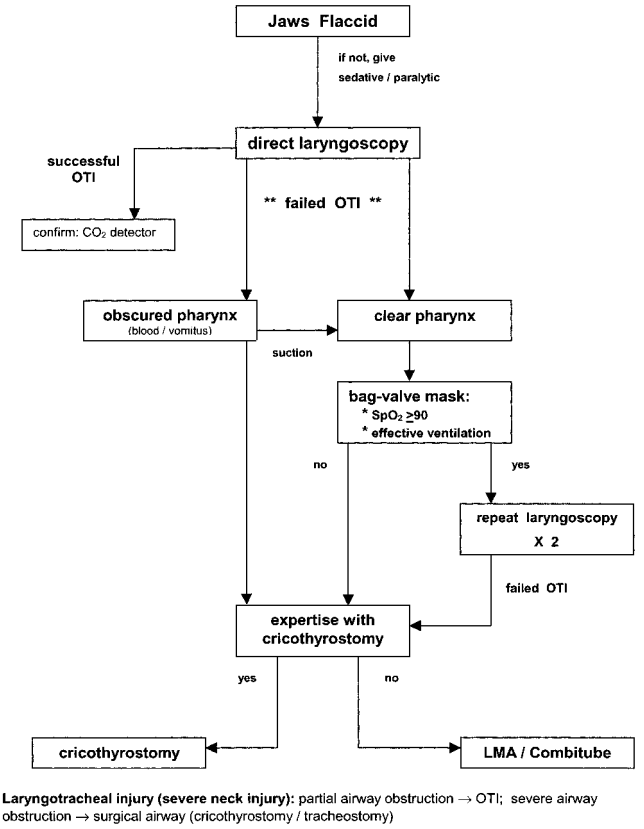

Fig. 1. *Procedural options for trauma patients needing emergency tracheal intubation.*

A sample drug regimen is listed in the Appendix.

- If OTI is successful, confirmation is documented by the detection of expired carbon dioxide.
- If OTI has failed and blood or vomitus completely obscures the pharynx, a cricothyrostomy is preferred.
- When the clinician has limited expertise with cricothyrostomy, a LMA or Combitube is inserted.
- If OTI has failed and the pharynx is clear, bag-valve mask ventilation is performed.
- If oxygenation and ventilation are not effective with bag-valve mask ventilation, a cricothyrostomy, LMA, or Combitube is inserted.
- If oxygenation and ventilation are effective with bag-valve mask ventilation, there are additional attempts at OTI.
- If OTI cannot be performed on the third attempt, a cricothyrostomy tube, LMA, or Combitube is inserted.
- Cricothyrostomy, LMA, and Combitube are temporary methods for airway control.
- If the patient has severe neck or laryngotracheal injury and partial airway obstruction is present, OTI is performed.
- If the patient has severe neck or laryngotracheal injury and severe airway obstruction is present, a surgical airway (cricothyrostomy or tracheostomy) is performed.

X. FUTURE INVESTIGATIONS

Need for Development of Safe and Effective Prehospital Tracheal Intubation Strategies

Seven published studies indicate that approximately 70% of patients in need of emergency tracheal intubation do not receive such care until trauma center arrival. This suggests that a large percentage of critically injured patients have a delay in optimal care.

Substantial ground EMS crew failure rates are described for nasotracheal intubation (30.3%) and orotracheal intubation without drug-assistance (33.5%). However, the failure rate for drug-assisted orotracheal intubation was only 7.6% in three EMS ground crew studies. These failure rates are similar to those found in larger aeromedical and trauma center studies.

The 92.4% ground EMS crew success rate for drug-assisted orotracheal intubation (1,244 patients) is similar to the 96.9% aeromedical crew success rate (3,213 patients). These data suggest that drug-assisted orotracheal intubation can be highly successful in the prehospital environment when an EMS system is appropriately developed.

In summary, future investigations should focus on the development and monitoring of tracheal intubation strategies in EMS systems. This includes the implementation of mechanisms to provide safe and effective orotracheal intubation, often with the need for drug-assistance. A plan must also be developed and implemented to manage failed orotracheal intubation with effective bag-valve mask ventilation, cricothyrostomy, LMA insertion, and Combitube placement.

EAST WEBSITE

To view the tables in this article, please visit the website of the Eastern Association for the Surgery of Trauma at http://www.east.org.

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Appendix 1 Sample Drug Regimen

Clinical Scenario	Drugs	Comments
Typical patient	Thiopental (3–5 mg/kg) *and* succinylcholine (1.5 mg/kg)	Give thiopental over a few seconds and rapidly follow with bolus of succinylcholine
GCS score $\leq$ 8	Lidocaine (1.5 mg/kg)	Give prior to thiopental and succinylcholine
Eye injury	Vecuronium (0.3 mg/kg) *or* rocuronium (1 mg/kg)	Replaces succinylcholine; neuromuscular blockade: vecuronium 120 min, rocuronium 45 min
HDI and awake	Thiopental (0.5–1 mg/kg) *or* etomidate (0.1–0.2 mg/kg)	Give with succinylcholine
HDI and coma	Succinylcholine (1.5 mg/kg)	

HDI, current or recent hemodynamic instability.