GUIDELINES FOR EMERGENCY TRACHEAL INTUBATION IMMEDIATELY FOLLOWING TRAUMATIC INJURY

An EAST Practice Management Guidelines Workgroup

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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 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 non-hypercarbic hypoxemia and aspiration, respectively. Airway obstruction can occur with cervical spine injury, severe cognitive impairment (GCS $\leq$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 non-hypercarbic, hypoxemia. Lung injury and non-hypercarbic, 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 for trauma patients undergoing emergency tracheal intubation is 6.5, however, the GCS varies across its spectrum (3 to 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 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 evidence-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

The committee goals were to develop evidence-based guidelines to characterize patients in need of emergency tracheal intubation immediately following traumatic injury and to delineate the most appropriate access procedure. Committee objectives were to review the literature to: 1)

delineate trauma patient conditions at-risk for respiratory system insufficiency during the immediate period following traumatic injury; 2) characterize trauma patients in need of emergency tracheal intubation immediately following traumatic injury; and 3) delineate the most appropriate access procedure for trauma patients undergoing emergency tracheal intubation. The focus was on patients who had sustained blunt trauma, penetrating trauma, or heat-related injury and had developed respiratory system insufficiency during the early postinjury period or required emergency tracheal intubation immediately postinjury (hour-1 or hour-2) in a prehospital, emergency department, or trauma center setting. Emergency tracheal procedures included orotracheal intubation, drug-assisted orotracheal intubation, nasotracheal intubation, fiberoptic-assisted tracheal intubation, cricothyrostomy, emergency tracheostomy, esophageal-tracheal Combitube insertion, and laryngeal mask airway insertion.

III. Process

A. Identification of the references:

- Medline search to identify potentially relevant articles:

  acute trauma-related respiratory system insufficiency:

  English language / human / 1970-2001 / all ages / all study types

  - title word: trauma and MESH: hypercarbia, airway obstruction, hypoventilation, aspiration, agitation, hypoxia, or hypoxemia – 255 articles
  - title word: injuries and MESH: hypercarbia, airway obstruction, aspiration, agitation, hypoxia, or anoxia – 108 articles
  - title: word traumatic and MESH: hypercarbia, airway obstruction, hypoventilation, aspiration, agitation, hypoxia, hypoxia (brain), anoxia, or hypoxemia – 177 articles
  - title word: injury and MESH: hypercarbia, airway obstruction, hypoventilation, aspiration, or hypoxia – 535 articles
  - title word; head and MESH: hypercarbia, airway obstruction, hypoventilation, aspiration, agitation, or hypoxia – 451 articles
  - title word: brain and MESH: hypercarbia, airway obstruction, hypoventilation, aspiration, agitation, or hypoxia – 802 articles
  - title word: trauma and title word: hypercapnia, airway obstruction, aspiration, secondary brain injury, or hypoxemia – 20 articles
  - title word: injuries and title word: hypercapnia or hypoxia – 2 articles
  - title word: traumatic and title word: airway obstruction, aspiration, agitation, hypoxia, or hypoxemia – 30 articles
  - title word: injury and title word: hypercapnia, airway obstruction, hypoventilation, aspiration, agitation, secondary hypoxia, or hypoxemia – 96 articles
  - title word: head and title word: airway obstruction, aspiration, agitation, secondary hypoxia, or hypoxemia – 108 articles
  - title word: brain and title word: hypercarbia, hypercapnia, airway obstruction, hypoventilation, aspiration, agitation, secondary brain injury, hypoxia, or hypoxemia – 150 articles

  acute trauma and emergency tracheal intubation:

  English language / human / 1980-2001 / all ages / all study types

        - title word: trauma, injury, injuries, traumatic, brain, or head and MESH: endotracheal intubation or tracheostomy – 792 articles
        - title word: airway and title word: injury, injuries, trauma, traumatic, head, or brain – 202 articles
        - title word: trauma and title word: intubation, endotracheal, tracheostomy, cricothyroidotomy, or cricothyrotomy - 87 articles
        - title word: injury and title word: intubation, endotracheal, tracheostomy, cricothyroidotomy, or cricothyrotomy - 72 articles
        - title word: injuries and title word: intubation, endotracheal, tracheostomy, cricothyroidotomy, or cricothyrotomy - 27 articles
        - title word: traumatic and title word: intubation, endotracheal, tracheostomy, cricothyroidotomy, or cricothyrotomy - 24 articles
        - title word: brain and title word: intubation, endotracheal, tracheostomy, cricothyroidotomy, or cricothyrotomy - 15 articles
        - title word: head and title word: intubation, endotracheal, tracheostomy, cricothyroidotomy, or cricothyrotomy - 41 articles
- patient investigation articles that addressed the guideline objectives were selected for comprehensive review
- the bibliography of reviews, letters to the editor, and meta-analyses were used to identify additional patient investigation articles
- committee members included 10 trauma surgeons with expertise in critical care, 1 emergency medical physician, and 1 neurosurgeon
- if an article investigated trauma and medical patients, the article was excluded if the trauma patient cohort was less than 50% of the total group
- the committee was given the complete bibliography and asked to recommend additional, appropriate articles, if any

B. Quality of the references:

The quality assessment instrument applied to the references was that adopted by the EAST Practice Management Guideline Committee:

Class I – randomized controlled trial

Class II – prospective clinical trial or retrospective analysis based on reliable data

Class III – retrospective case series or database review

C. Literature review assignments:

- Committee members were assigned articles that described emergency tracheal intubation in acutely injured trauma patients.
- The committee chair reviewed all the tracheal intubation articles.
- The committee chair summarized all articles that described trauma patient conditions at-risk for respiratory system insufficiency.

D. Documentation of literature results:

manuscript data forms:

- A manuscript data form was constructed to standardize the information collected from each tracheal intubation article.
- Manuscript data form elements:
    - author, title, publication citation
    - clinical setting

- percent trauma patients (50-89%, ≥90%)
- number of trauma patients
- clinical scenarios:
  cardiac arrest, cervical spine injury, severe cognitive impairment (GCS ≤8), heat-related injury, severe maxillofacial injury, severe neck injury, shock, thoracic injury, or multiple (diverse)
- manifestations of respiratory system insufficiency (e.g., hypoxemia, airway obstruction)
- patient traits (e.g., GCS, ISS, mortality)
- clinical indications for emergency tracheal intubation (described in study protocol and/or as a study conclusion)
- tracheal intubation procedures (orotracheal intubation, drug-assisted orotracheal intubation, nasotracheal intubation, fiberoptic-assisted tracheal intubation, cricothyrostomy, emergency tracheostomy, esophageal-tracheal Combitube insertion, and laryngeal mask airway insertion):
  - patient attempts
  - patient successes
  - patient complications
  - indications for procedure
- pharmacological objectives described in studies of drug-assisted orotracheal intubation (sedation, paralysis, and prevention of intracranial hypertension, hemodynamic instability, vomiting, and intra-ocular content extrusion)

management of manuscript data form information:

- committee members and the chair reviewed all tracheal intubation articles and completed a data form for each article
- any discrepancy between information on the chair's data form and the committee member's data form was reconciled by further review of the article
- information from the data form was entered into a computerized database
- data were harvested from the computerized database to address clinically meaningful queries
- data were displayed in tables and organized to (a) characterize trauma patients in need of emergency tracheal intubation immediately following traumatic injury and (b) delineate the most appropriate access procedure for trauma patients undergoing emergency tracheal intubation
- all tables were disseminated to each committee members for review and comments
- based on the literature-evidence, recommendations were made

IV. Recommendations to Characterize Patients in Need of Emergency Tracheal Intubation Immediately Following 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-review 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 $\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 $\leq$ 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 Following 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% (14 to 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 to 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 to 45%) and associated hypoxemia (15 to 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] 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 following 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% (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 $\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 ≤8) Need Emergency Tracheal Intubation

Background:

There is extensive literature to indicate that trauma patients with severe cognitive impairment (GCS ≤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 found a significant reduction in mortality with prehospital tracheal intubation.[30] Cooper showed a decrease in injury-related complications and Hicks demonstrated a reduction in hypoxemia during transfer to a trauma center.[161,198] The Winchell study evaluated the impact of prehospital intubation on mortality in blunt trauma patients with GCS ≤8. Paramedics were permitted to perform orotracheal intubation (OTI) without drug-assistance when hypoventilation was present. Of the patients with severe brain injury and extra-cranial trauma, the intubated and non-intubated patients had similar GCS, head/neck AIS, and injury severity scores. The mortality rate was significantly lower for the intubated patients (35.6%) when compared to those without intubation (57.4%; relative risk 0.62; $P<<0.0001$). For the patients with isolated severe brain injury, the intubated and non-intubated patients had similar GCS, head/neck AIS, and injury severity scores. The mortality rate was significantly lower for the intubated patients (22.8%) when compared to those without intubation (49.6%; relative risk 0.46; $P<<0.0001$).

Thirty-one studies of trauma patients undergoing emergency tracheal intubation provide evidence that patients with severe cognitive impairment (GCS ≤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 ≤8) was often not available. In virtually all studies, severe cognitive impairment (GCS ≤8) was a protocol criterion for tracheal intubation. Also, some investigators, after study analysis, concluded that patients with severe cognitive impairment (GCS ≤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 following 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 following 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 $\leq$8).[149,151,200-203]

Level I Recommendation:

Trauma patients with severe cognitive impairment (GCS $\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:

Following smoke inhalation, acute respiratory system insufficiency can be due to carbon monoxide toxicity and thermal or combustion-product tissue injury. Carbon monoxide can create central nervous system hypoxia and tissue injury can lead to supra-glottic, glottic, or infra-glottic 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% (4 to 27%) of burn patients.[146,148,217-219] The incidence of smoke inhalation injury for patients who have burn injury is 10.7% (3 to 60%).[134,135,140,147,220-225]

Clinical indicators of smoke inhalation include:

- 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 pathology 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% (605/972). Six groups of patients with smoke inhalation and cutaneous burns (40-55%) revealed an overall intubation rate of 77.5% (502/648; 95% CI, 74.3-80.7%),[131-135,224] whereas 5 groups of patients with isolated smoke inhalation had an overall intubation rate of 41.7% (65/156, 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 to the patients without burns ($P<<0.001$). 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% (38/168; 95% CI, 16.3-28.9%).[139-143] The rate of tracheal intubation in these mixed patients was much lower when compared to the 77.5% rate in the studies where all patients had cutaneous burns ($P<<0.001$).

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

Haponik 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% versus 8.0%; $P<0.0001$) and a higher rate of facial/neck cutaneous burns (92.9% versus 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 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:

- airway obstruction
- severe cognitive impairment (GCS $\leq$8)
- a major cutaneous burn ($\geq$ 40%)

- impending airway obstruction:
    1. moderate-to-severe facial burn
    2. moderate-to-severe oropharyngeal burn
    3. moderate-to-severe airway injury seen on endoscopy
- 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-review 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; and
    f) prevent intra-ocular 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; and
    e) carbon dioxide monitoring.
4. Cricothyrostomy is appropriate when emergency tracheal intubation is needed and the vocal cords can not be visualized during laryngoscopy or the pharynx is obscured by copious amounts of blood or vomitus.

Level III

1. 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 orotracheal intubation (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 while 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 ED/trauma center staff 11.4%.[40,68,237] The intubation failure rate for OTI without drug-assistance was higher for EMS ground crews when compared to aeromedical crews or TC/ED settings. The GCS for patients who had OTI without drug-assistance was 3 or 4.[26,40,42] The OTI success rate was greater for the GCS 3 patients when compared to the GCS 4 patients (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% (5,745/5,963) (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 trauma center staff.[14,18,34,40,49,64,68,80,111,115,233,234,236,241] The GCS, 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 approaches, 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 (1044/1110) 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 QA process, and the use of tracheal intubation confirmation by CO_2 detectors and/or tube aspiration devices.

There is a recent prospective, ground EMS study where 117 patients with traumatic brain injury (GCS $\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 esophageal-tracheal Combitube placement. The drug-assisted OTI success rate was 84.6% (99/117). Of the 18 patients with unsuccessful OTI, 17 (94.4%) were managed with an esophageal-tracheal Combitube. The pre-intubation SpO_2 for the 117 patients was 89% and the post-intubation SpO_2 was 98%.

The overall complication rate for OTI with drug-assistance was calculated to be 3.6% (138/3,886) 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 intra-ocular 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 has 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% (476/620): 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 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 percent 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).[14,18,21-24,26,27,30,32,36-40,44,45,49,50,57,64,68,73-75,78,80,81,88,89,109,113,115,116,118,119,144,145,228,230,232,235,237,239] 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% (471/595), OTI with drug-assistance 96.3% (5,745/5,963), NTI 76.8% (476/620), and cricothyrostomy 95.7% (421/440) (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 to OTI with drug-assistance ($P<<0.001$). 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 to OTI with drug-assistance ($P<<0.001$).

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 (1044/1110).[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 CO_2 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 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% (4,858/4,989) (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 $\geq$ 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 percent 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% (2,134/2,201) in 3 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 $\leq$8).[240] Patients were managed with rapid sequence drug-assistance and had an overall intubation success rate of 99.1% (116/117). Of those successfully intubated, 99 had OTI (85.3%) and 17 were managed by esophageal-tracheal Combitube placement (14.7%). The pre-intubation SpO_2 was 89% for the entire group and the post-intubation SpO_2 was 98%.

Twenty trauma center studies have described 23 patient groups where the overall emergency intubation success rate was 99.9% (3,398/3,401) (Table 22).[18,19,24,39,40,49,57,58,64,67,68,80,81,88,113,118,118,119,145,239] 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 upon trauma center arrival (Table 23).[20,33,42,46,82,128] Only 27.4% were intubated prior to 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 $\leq$8) (Table 24).[27,30,30,44,69] Prehospital intubation was lower in the patients managed by EMS ground crews (33.4% [649/1,944]) when compared to those treated by aeromedical crews (85.1% [883/1,038]).

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 Material and Methods section of the manuscript. 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 paper also emphasizes the importance of adequate training, clinical experience, and quality assurance 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-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]
- Italian Societies of Neurosurgery and Anesthesia and Intensive Care[202]
- American College of Surgeons Committee on Trauma[149]
- Brain Trauma Foundation and American Association of Neurological Surgeons[200,201]
- 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; and
- prevent intra-ocular content extrusion.

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.

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 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% (407/425) 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% (51/530) 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 to 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 non-visualized 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 can not 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 can not 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% (40/44; 95% CI, 82.4-99.4%). Patients undergoing emergency Combitube placement were typically GCS 3 following 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 non-visualized 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 2, emergency department 1, and trauma center 2. Patients undergoing emergency LMA placement were typically GCS 3 following 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 were typically GCS 3 following 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 non-visualized 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 3 following 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. A 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, 1987,[72] Broos, 1993,[62] Gentleman, 1992,[199] Gerich, 1998,[74] Jacobs, 1984,[77] Koenig, 1992,[233] Lee, 1992,[225] Levy, 1997,[113] Masanes,1994,[227] McBrien, 1992,[19] Muehlberger, 1988,[137] Ochs, 2000,[51] Plewa, 1997,[236] Redan, 1991,[18] Rhee, 1994,[44] Sakles, 1998,[237] Shackford, 1981,[188] Sharma, 1996,[182] Shatney, 1995,[89] Syverud, 1988,[37] Tayal, 1999,[229] Thomas, 1999,[50] Trupka, 1994,[25] Vicario, 1983,[159] and Winchell, 1997.[30] There were no data class I studies cited.

Percent of Trauma Patients

The majority of the cited tracheal intubation studies describe patients with a trauma mechanism. A trauma mechanism existed in 50-89% of the patients in the following studies: Boyle, 1993,[61] Erlandson, 1989,[59] Ma, 1998,[228] McGill, 1982,[55] Rose, 1994,[73] Sakles, 1998,[237] Slater, 1998,[48] Syverud, 1988,[37] Tayal, 1999,[229] Thomas, 1999,[50] and Thompson, 1982.[230] Intubation studies were not cited when <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 $\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 $\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 intra-ocular content extrusion.

Cricothyrostomy is appropriate when emergency tracheal intubation is needed and the vocal cords can not 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, page 80.

- 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; and
    6. prevent intra-ocular content extrusion.
- 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 ≤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 minutes, Rocuronium 45 minutes
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

- 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 percent 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.

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Table 1. Tracheal Intubation Studies Providing Evidence That Trauma Patients with Airway Obstruction Need Emergency Intubation

Author	Year	Setting	Scenario	Patients†	Endorsement
Kollmorgen	1994	TC	Ch	100	prot
Meschino	1992	TC	CSI	454	prot
Blostein	1998	AR	Div	10	prot
Gabram	1989	AR	Div	136	prot
Gerich	1998	AR	Div	383	prot
Murphy-Macabobby	1992	AR	Div	119	prot
Sing	1998	AR	Div	84	prot
Thomas	1999	AR	Div	722	prot
Xeropotamos	1993	AR	Div	11	prot
Spaite	1990	GR	Div	16	prot
Dunham	1989	TC	Div	2444	prot
Talucci	1988	TC	Div	335	prot
Salvino	1993	AR/TC	Div	1240	prot
Dolin	1992	TC	MFI	100	prot
Eggen	1993	ED	Nk	114	both
Edwards	1987	TC	Nk	20	both
Grewal	1995	TC	Nk	57	concl
Gussack	1988	TC	Nk	21	both
Hartmann	1985	TC	Nk	4	concl
Herrin	1979	TC	Nk	87	concl
Levy	1997	TC	Nk	29	concl
				6486	

AR, aeromedical; ED, emergency department; GR, ground EMS; TC, trauma center; Ch, severe chest injury; CSI, cervical spine injury; Div, diverse trauma patient scenarios; MFI, maxillofacial injury; Nk, severe neck injury; Patients†, number of patients assessed in each intubation study (the percentage with airway obstruction was often not available); prot, airway obstruction was intubation protocol criterion; concl, author concluded intubation is needed for airway obstruction; both, protocol and author conclusion endorsement

Reference numbers for table citations are listed on page 78 and 79

Table 2. Tracheal Intubation Studies Providing Evidence That Trauma Patients with Hypoventilation Need Emergency Intubation

Author	Year	Setting	Scenario	Patients†	Endorsement
Ochs	2000	GR	Arr	14	prot
Kollmorgen	1994	TC	Ch	100	prot
Hsiao	1993	GR	Cog	16	prot
Murray	2000	GR	Cog	852	prot
Winchell	1997	GR	Cog	1092	prot
Meschino	1992	TC	CSI	454	prot
Blostein	1998	AR	Div	10	prot
Gabram	1989	AR	Div	136	prot
Murphy-Macabobby	1992	AR	Div	119	prot
Sing	1998	AR	Div	84	prot
Sloane	2000	AR	Div	47	prot
Thomas	1999	AR	Div	722	prot
Eckstein	2000	GR	Div	496	prot
Dunham	1989	TC	Div	2444	prot
Talucci	1988	TC	Div	335	prot
Trupka	1994	TC	Div	125	prot
Eckstein	2000	GR/TC	Div	496	prot
				7542	

AR, aeromedical; ED, emergency department; GR, ground EMS; TC, trauma center;
Arr, arrest; Ch, severe chest injury; Cog, patients with severe cognitive impairment (GCS $\leq$8); CSI, cervical spine injury; Div, diverse trauma patient scenarios;
Patients†, number of patients assessed in each intubation study (the percentage with hypoventilation was often not available);
prot, hypoventilation was intubation protocol criterion

Table 3. Tracheal Intubation Studies Providing Evidence That Trauma Patients with Severe Hypoxemia Need Emergency Intubation

Author	Year	Setting	Scenario	Patients†	Endorsement
Barone	1986	ED	Ch	140	concl
Kollmorgen	1994	TC	Ch	100	prot
Garner	1999	AR	Div	34	prot
Rose	1994	AR	Div	100	prot
Rose	1994	AR	Div	100	prot
Slater	1998	AR	Div	325	prot
Thomas	1999	AR	Div	722	prot
Dunham	1989	TC	Div	2444	prot
Trupka	1994	TC	Div	125	both
				4090	

AR, aeromedical; ED, emergency department; GR, ground EMS; TC, trauma center; Ch, severe chest injury; Div, diverse trauma patient scenarios;
Patients†, number of patients assessed in each intubation study (the percentage with severe hypoxemia was often not available);
prot, severe hypoxemia was intubation protocol criterion; concl, author concluded intubation is needed for severe hypoxemia; both, protocol and author conclusion endorsement

Table 4. Tracheal Intubation Studies Providing Evidence That Trauma Patients with Respiratory Distress Need Emergency Intubation

Author	Year	Setting	Scenario	Patients†	Endorsement
Kollmorgen	1994	TC	Ch	100	prot
Shatney	1995	TC	CSI	150	prot
Gabram	1989	AR	Div	136	prot
Gerich	1998	AR	Div	383	prot
Murphy-Macabobby	1992	AR	Div	119	prot
Rose	1994	AR	Div	100	prot
Rose	1994	AR	Div	100	prot
Slater	1998	AR	Div	325	prot
Thomas	1999	AR	Div	722	prot
Eckstein	2000	GR	Div	496	prot
Trupka	1994	TC	Div	125	prot
Vijayakumar	1998	TC	Div	160	prot
Eggen	1993	ED	Nk	114	both
Gussack	1988	TC	Nk	21	both
Herrin	1979	TC	Nk	87	concl
Levy	1997	TC	Nk	29	concl
Reece	1988	TC	Nk	51	concl
				3218	

AR, aeromedical; ED, emergency department; GR, ground EMS; TC, trauma center;
Ch, severe chest injury; CSI, cervical spine injury; Div, diverse trauma patient scenarios;
Nk, severe neck injury;
Patients†, number of patients assessed in each intubation study (the percentage with respiratory distress was often not available);
prot, respiratory distress was intubation protocol criterion; concl, author concluded intubation is needed for respiratory distress; both, protocol and author conclusion endorsement

Table 5. Tracheal Intubation Studies Providing Evidence That Trauma Patients with Severe Cognitive Impairment (GCS ≤8) Need Emergency Intubation

Author	Year	Setting	Scenario	Patients[†]	Endorsement
Boswell	1995	AR	Cog	353	prot
Rhee	1994	AR	Cog	106	prot
Winchell	1997	AR	Cog	502	both
Winchell	1997	GR	Cog	1092	both
Gentleman	1992	TC	Cog	600	concl
Hicks	1994	TC	Cog	120	concl
Vicario	1983	TC	Cog	34	concl
Hsiao	1993	GR/TC	Cog	60	both
Shatney	1995	TC	CSI	150	prot
Fischer	1984	AR	Div	237	prot
Gabram	1989	AR	Div	136	prot
Garner	1999	AR	Div	34	prot
Gerich	1998	AR	Div	383	prot
Murphy-Macabobby	1992	AR	Div	119	prot
Rose	1994	AR	Div	100	prot
Sing	1998	AR	Div	84	prot
Slater	1998	AR	Div	325	prot
Sloane	2000	AR	Div	47	prot
Syverud	1988	AR	Div	74	prot
Thomas	1999	AR	Div	722	prot
Vilke	1994	AR	Div	567	prot
Dunham	1989	TC	Div	2444	prot
Ligier	1991	TC	Div	66	prot
Norwood	1994	TC	Div	229	prot
Rotondo	1993	TC	Div	231	prot
Talucci	1988	TC	Div	335	prot
Trupka	1994	TC	Div	125	both
Vijayakumar	1998	TC	Div	160	prot
Salvino	1993	AR/TC	Div	1240	prot

Author	Year	Setting	Scenario	Patients†	Endorsement
Eckstein	2000	GR/TC	Div	496	both
Dolin	1992	TC	MFI	100	both
Eggen	1993	ED	Nk	114	both
				11,385	

AR, aeromedical; ED, emergency department; GR, ground EMS; TC, trauma center; Cog, patients with severe cognitive impairment (GCS <8); CSI, cervical spine injury; Div, diverse trauma patient scenarios; MFI, maxillofacial injury; Nk, severe neck injury; Patients†, number of patients assessed in each intubation study (the percentage with severe cognitive impairment was often not available);
prot, severe cognitive impairment was intubation protocol criterion; concl, author concluded intubation is needed for severe cognitive impairment; both, protocol and author conclusion endorsement

Table 6. Tracheal Intubation Studies Providing Evidence That Trauma Patients with Cardiac Arrest Need Emergency Intubation

Author	Year	Setting	Scenario	Patients†	Endorsement
Copass	1984	GR	Arr	131	both
Ochs	2000	GR	Arr	14	prot
Hsiao	1993	GR	Cog	16	prot
Gabram	1989	AR	Div	136	prot
Garner	1999	AR	Div	34	prot
Xeropotamos	1993	AR	Div	11	prot
Eckstein	2000	GR	Div	496	prot
Dunham	1989	TC	Div	2444	prot
Trupka	1994	TC	Div	125	both
Vijayakumar	1998	TC	Div	160	prot
				3,567	

AR, aeromedical; ED, emergency department; GR, ground EMS; TC, trauma center;
Arr, arrest; Cog, patients with severe cognitive impairment (GCS $\leq$8); Div, diverse trauma patient scenarios;
Patients†, number of patients assessed in each intubation study (the percentage with cardiac arrest was often not available);
prot, cardiac arrest was intubation protocol criterion; concl, author concluded intubation is needed for cardiac arrest; both, protocol and author conclusion endorsement

Table 7. Tracheal Intubation Studies Providing Evidence That Trauma Patients with Severe Hemorrhagic Shock Need Emergency Intubation

Author	Year	Setting	Scenario	Patients†	Endorsement
Barone	1986	ED	Ch	140	concl
Kollmorgen	1994	TC	Ch	100	prot
Shatney	1995	TC	CSI	150	prot
Gerich	1998	AR	Div	383	prot
Thomas	1999	AR	Div	722	prot
Dunham	1989	TC	Div	2444	prot
Norwood	1994	TC	Div	229	prot
Trupka	1994	TC	Div	125	concl
Salvino	1993	AR/TC	Div	1240	prot
Dolin	1992	TC	MFI	100	both
				5633	

AR, aeromedical; ED, emergency department; GR, ground EMS; TC, trauma center;
Ch, severe chest injury; CSI, cervical spine injury; Div, diverse trauma patient scenarios;
MFI, maxillofacial injury;
Patients†, number of patients assessed in each intubation study (the percentage with severe shock was often not available);
prot, severe shock was intubation protocol criterion; concl, author concluded intubation is needed for severe shock; both, protocol and author conclusion endorsement

Table 8. Success (Failure) Rates for Orotracheal Intubation Without Drug Assistance

Author	Year	Setting	Scenario	GCS	Attempts	Success	Percent
Hsiao	1993	GR	Cog	3	16	16	100
Eckstein	2000	GR	Div	.	148	93	63
					164	**109**	**66.5%**
Ma	1998	AR	Div	.	69	46	67
O'Brien	1988	AR	Div		3	3	100
Slater	1998	AR	Div		37	35	95
Syverud	1988	AR	Div		3	3	100
Vilke	1994	AR	Div	4	170	143	84
					282	**230**	**81.6%**
Sakles	1998	ED	Div	.	94	86	91
Ligier	1991	TC	Arr	3	30	28	93
Ligier	1991	TC	Div	.	20	13	65
Mandavia	2000	TC	Nk	.	5	5	100
					149	**132**	**88.6%**
			All studies:		**595**	**471**	**79.2%**

AR, aeromedical; ED, emergency department; GR, ground EMS; TC, trauma center; Arr, cardiac arrest; Cog, patients with severe cognitive impairment (GCS $\leq$8); Div, diverse trauma patient scenarios; Nk, severe neck injury

Table 9. Complication Rate for Orotracheal Intubation Without Drug Assistance.

Author	Year	Setting	Scenario	Patients	Complications	Percent
Vilke	1994	AR	Div	143	40	28.0%
Rhee	1990	TC	CSI	2	0	0%
Talucci	1988	TC	Div	60	0	0%
Mandavia	2000	TC	Nk	5	0	0%
				210	**40**	
			complication rate:		**19.0%**	

AR, aeromedical; TC, trauma center;

CSI, cervical spine injury; Div, diverse trauma patient scenarios; Nk, severe neck injury

Table 10. Intubation Success Rate for Orotracheal Intubation with Drug Assistance

Author	Year	Setting	Scenario	GCS	Attempts	Success	Percent
Rhee	1994	AR	Cog		33	25	76
Gabram	1989	AR	Div	7	24	24	100
Gerich	1998	AR	Div	.	379	373	98
Ma	1998	AR	Div	.	40	39	98
Murphy-Macabobby	1992	AR	Div	.	116	115	99
Rose	1994	AR	Div	.	34	30	88
Sing	1998	AR	Div	.	84	80	95
Slater	1998	AR	Div	7	288	279	97
Sloane	2000	AR	Div	6	47	46	98
Syverud	1988	AR	Div	8	71	68	96
Thomas	1999	AR	Div	9	708	686	97
Vilke	1994	AR	Div	7	156	140	90
Salvino	1993	AR/TC	Div	.	1233	1210	98
					3213	**3115**	**96.9%**
Sakles	1998	ED	Div	.	515	511	99
Thompson	1982	ED	Div	.	48	42	88
					563	**553**	**98.2%**
Wang	2000	GR	Div	.	17	7	41
Wayne	1999	GR	Div	.	1110	1044	94
Davis	2001	GR	Div		117	99	85
					1244	**1150**	**92.4%**
Koenig	1992	TC	Cog	.	46	46	100
Redan	1991	TC	Comb		60	57	95
Muckart	1997	TC	CSI	15	2	2	100
Talucci	1988	TC	CSI	.	7	7	100
Ligier	1991	TC	Div	.	44	44	100
Plewa	1997	TC	Div	.	20	20	100

Author	Year	Setting	Scenario	GCS	Attempts	Success	Percent
Rotondo	1993	TC	Div	.	198	196	99
Sloane	2000	TC	Div	11	267	263	99
Vijayakumar	1998	TC	Div	12	151	147	97
Myles	1994	TC	MFI	3	1	0	0
Grewal	1995	TC	Nk	.	14	14	100
Hartmann	1985	TC	Nk	15	1	1	100
Mandavia	2000	TC	Nk	.	42	42	100
Shearer	1993	TC	Nk	.	90	88	98
					943	**927**	**98.3**
All studies					**5963**	**5745**	**96.3%**

AR, aeromedical; ED, emergency department; GR, ground EMS; TC, trauma center; Cog, patients with severe cognitive impairment (GCS ≤8); Comb, combative; CSI, cervical spine injury; Div, diverse trauma patient scenarios; MFI, maxillofacial injury; Nk, severe neck injury

Table 11. Complication Rates for Patients Undergoing Orotracheal Intubation with Drug Assistance

Author	Year	Setting	Scenario	Patients	Complications	Percent
Rhee	1994	AR	Cog	25	4	16
Gerich	1998	AR	Div	373	48	13
Ma	1998	AR	Div	39	0	0
Murphy-Macabobby	1992	AR	Div	115	0	0
Rose	1994	AR	Div	30	2	7
Sing	1998	AR	Div	80	15	19
Slater	1998	AR	Div	229	35	15
Sloane	2000	AR	Div	46	6	13
Vilke	1994	AR	Div	140	0	0
				1077	**110**	**10.2%**
Tayal	1999	ED	Div	417	6	1
Thompson	1982	ED	Div	42	2	5
				459	**8**	**1.7%**
Wayne	1999	GR	Div	**1582**	**6**	**3.8%**
Koenig	1992	TC	Cog	46	0	0
Redan	1991	TC	Comb	57	1	2
Criswell	1994	TC	CSI	71	0	0
Muckart	1997	TC	CSI	2	0	0
Redan	1991	TC	CSI	3	0	0
Rhee	1990	TC	CSI	15	0	0
Talucci	1988	TC	CSI	7	0	0
Sloane	2000	TC	Div	263	13	5
Talucci	1988	TC	Div	260	0	0
Flancbaum	1986	TC	Nk	1	0	0

Author	Year	Setting	Scenario	Patients	Complications	Percent
Hartmann	1985	TC	Nk	1	0	0
Mandavia	2000	TC	Nk	42	0	0
				768	**14**	**1.8%**
All Studies				**3886**	**138**	**3.6%**

AR, aeromedical; ED, emergency department; GR, ground EMS; TC, trauma center; Cog, patients with severe cognitive impairment (GCS ≤8); Comb, combative; CSI, cervical spine injury; Div, diverse trauma patient scenarios; Nk, severe neck injury

Table 12. Nasotracheal Intubation Success Rates

Author	Year	Setting	Scenario	GCS	Attempts	Successes	Percent
Rhee	1994	AR	Cog		44	35	80
Gabram	1989	AR	Div		76	59	78
O'Brien	1988	AR	Div	7	65	62	95
Thomas	1999	AR	Div		16	11	69
Vilke	1994	AR	Div	6	315	237	75
					516	**404**	**78.3%**
Sakles	1998	ED	Div	.	8	6	75
Eggen	1993	ED	Nk	.	6	4	67
					14	**10**	**71.4%**
Cwinn	1987	GR	Div	.	22	17	77
O'Brien	1989	GR	Div	.	54	36	67
					76	**53**	**69.7%**
Ligier	1991	TC	Div	.	10	6	60
Shearer	1993	TC	Nk	.	4	3	75
					14	**9**	**64.3%**
all studies					**620**	**476**	**76.8%**

AR, aeromedical; ED, emergency department; GR, ground EMS; TC, trauma center; Cog, patients with severe cognitive impairment (GCS ≤8); Div, diverse trauma patient scenarios; Nk, severe neck injury

Table 13. Nasotracheal Intubation Complications

Author	Year	Setting	Scenario	Patients	Complications	Percent
Rhee	1994	AR	Cog	35	7	20
O'Brien	1988	AR	Div	62	3	5
Vilke	1994	AR	Div	237	14	6
Eggen	1993	ED	Nk	4	0	0
Rosen	1997	GR/TC	MFI	82	0	0
Holley	1989	TC	CSI	103	0	0
Redan	1991	TC	CSI	4	0	0
Rhee	1990	TC	CSI	2	0	0
Shatney	1995	TC	CSI	7	0	0
Talucci	1988	TC	Div	12	0	0
Wright	1992	AR/TC	CSI	25	1	4
all studies				**573**	**25**	**4.4%**

AR, aeromedical; ED, emergency department; GR, ground EMS; TC, trauma center; Cog, patients with severe cognitive impairment (GCS $\leq$8); CSI, cervical spine injury; Div, diverse trauma patient scenarios; MFI, maxillofacial injury; Nk, severe neck injury

Table 14. Patients with Fiberoptic-directed Intubation

Author	Year	Setting	Scenario	Attempts	Successful	Complications
Grover	1978	TC	Ch	1	1	.
Mlinek	1990	ED	Div	4	4	0
Mulder	1975	TC	Div	11	11	0
Neal	1996	ED	MFI	1	1	0
Mandavia	2000	TC	Nk	12	9	1
Reece	1988	TC	Nk	5	1	.
Shearer	1993	TC	Nk	8	8	.
				42	**35**	
				success rate 83.3% (72.0-94.6%)		

ED, emergency department; TC, trauma center;
Ch, chest injury; Div, diverse trauma patient scenarios; MFI, maxillofacial injury; Nk, severe neck injury

Table 15. Orotracheal Intubation is Most Common Route for Emergency Tracheal Intubation (studies where OTI and Non-OTI routes were used)

Author	Year	Scenario	OTI	NTI	Cric	Trach	Total	% OTI
Ligier	1991	Arr	28	1	2	0	31	90
Grover	1979	Ch	4	0	0	1	5	80
Boswell	1995	Cog	171	96	0	0	267	64
Rhee	1994	Cog	25	35	0	0	60	41
Winchell	1997	Cog	422	0	9	0	431	98
Redan	1991	Comb	57	40	3	0	100	57
Criswell	1994	CSI	71	0	2	0	73	97
Holley	1989	CSI	30	103	0	0	133	23
Redan	1991	CSI	3	4	0	0	7	43
Rhee	1990	CSI	17	2	2	0	21	81
Shatney	1995	CSI	48	7	0	0	55	87
Wright	1992	CSI	26	25	2	0	53	49
Falcone	1996	Div	19	118	6	0	143	13
Falcone	1996	Div	36	56	3	0	95	38
Gabram	1989	Div	67	59	0	0	126	53
Garner	1999	Div	33	0	1	0	34	97
Gerich	1998	Div	373	0	8	0	381	98
Ma	1998	Div	202	0	8	0	210	96
Murphy-Macabobby	1992	Div	115	0	4	0	119	97
O'Brien	1988	Div	3	62	2	0	67	4
Rose	1994	Div	24	49	0	0	73	33
Rose	1994	Div	63	33	0	0	96	66
Sing	1998	Div	80	0	3	0	83	96
Syverud	1988	Div	71	0	1	0	72	99
Thomas	1999	Div	686	11	9	0	706	97
Vilke	1994	Div	283	237	18	0	538	53
Xeropotamos	1993	Div	132	0	11	0	143	92
Sakles	1998	Div	597	6	7	0	610	98
Thompson	1982	Div	42	1	5	0	48	88
Cwinn	1987	Div	14	17	0	0	31	45

Author	Year	Scenario	OTI	NTI	Cric	Trach	Total	% OTI
Wayne	1999	Div	1582	0	3	0	1585	99
Deo	1994	Div	7	16	2	0	25	28
Dunham	1989	Div	1145	0	13	0	1158	99
Ligier	1991	Div	57	6	2	1	66	86
Norwood	1994	Div	223	0	6	0	229	97
Rhee	1990	Div	213	17	7	0	237	90
Rotondo	1993	Div	196	0	2	0	198	99
Talucci	1988	Div	320	12	3	0	335	96
Vijayakumar	1998	Div	151	4	5	0	160	94
Salvino	1993	Div	1210	0	30	0	1240	98
Wright	1992	Div	618	357	12	0	987	63
Dolin	1992	MFI	33	0	2	0	35	94
Eggen	1993	Nk	9	4	0	13	26	35
Edwards	1987	Nk	4	3	0	5	12	33
Grewal	1995	Nk	14	0	3	15	32	44
Grover	1979	Nk	7	0	0	1	8	88
Gussack	1988	Nk	12	0	0	6	18	67
Herrin	1979	Nk	52	20	0	15	87	60
Levy	1997	Nk	8	0	0	4	12	67
Mandavia	2000	Nk	47	0	0	2	49	96
Shearer	1993	Nk	88	3	0	7	98	90
			9738	**1404**	**196**	**70**	**11408**	
			85.4%	**12.3%**	**1.7%**	**0.6%**		**71.4%**

OTI procedures: 85.4% (study average 71.1%)

non-OTI procedures: 14.6%

OTI, orotracheal intubation; Arr, cardiac arrest; Ch, chest injury; Cog, patients with severe cognitive impairment (GCS ≤8); Comb, combative; CSI, cervical spine injury; Div, diverse trauma patient scenarios; MFI, maxillofacial injury; Nk, severe neck injury; NTI, nasotracheal intubation; Cric, cricothyrostomy; Trach, tracheostomy

Table 16. Intubation Success and Failure Rates

	Patient Attempts	Patient Successes	% Successes	% Failures
OTI – no drugs	**595**	**471**	**79.2%**	**20.8% (17.5-24.1)**
EMS ground	164	109	66.5%	
aeromedical	282	230	81.6%	
ED / TC	149	132	88.6%	
OTI – with drugs	**5963**	**5745**	**96.3%**	**3.7% (3.2-4.2)**
EMS ground	1244	1150	92.4%	
aeromedical	3213	3115	96.9%	
ED / TC	1506	1480	98.3%	
NTI	**620**	**476**	**76.8%**	**23.2% (19.9-26.5)**
EMS ground	76	53	69.7%	
aeromedical	516	404	78.3%	
ED / TC	28	19	67.9%	
Cricothyrostomy	**440**	**421**	**95.7**	**4.3% (2.4-6.2)**
EMS ground	217	203	93.5%	
aeromedical	208	204	98.1%	
ED / TC	15	14	93.3%	

OTI, orotracheal intubation; ED/TC, emergency department or trauma center; NTI, nasotracheal intubation

Table 17. Tracheal Intubation Complication Rates

	Successful	Complications	Percent Complications	% Attempts by EMS ground crew
OTI – no drugs	210	40	**19.0%** (13.7 - 24.3)	0%
OTI – with drugs	3886	138	**3.6%** (3.0 - 4.2)	40.7%
NTI	573	25	**4.4%** (2.7 - 6.1)	0%
Cricothyrostomy	530	51	**9.6%** (7.1 - 12.1)	30.9

poor documentation of EMS ground crew complications
for OTI without drugs and NTI

OTI, orotracheal intubation; NTI, nasotracheal intubation

Table 18. Impact of Drug-Assisted OTI on Tracheal Intubation Success Rates (diverse patients in aeromedical setting)

	Drug-Assisted OTI Used			
	no	**yes**	**p-value**	**comments**
Ma, 1998	78%	95%	.01	2 groups; increased success rate
Rose, 1994	73%	96%	<.0001	2 groups; increased success rate
Syverud, 1988	7%	96%	<.0001	74 patients needed intubation; 43 patients had attempt at OTI without drugs; 3 were successful (7%); of remaining 71, 68 had successful OTI with drugs (96%); increased success rate
Falcone, 1996	97%	100%	.2	2 groups of patients; majority intubations in both groups by NTI; 2nd group had less NTI and same percent cricothyrostomies

OTI, orotracheal intubation; NTI, nasotracheal intubation

Table 19. Overall Tracheal Intubation Success Rate with Multiple Procedures -- Aeromedical Studies (21 patient groups; 17 studies)

Author	Year	Patients	OTI	NTI	ETI	Cric	Trach	Rate
Boswell	1995	267	0	0	1	0	0	90%
Rhee	1994	106	1	1	0	1	0	100%
Baxt	1987	97	0	0	1	1	0	92%
Falcone	1996	143	1	1	0	1	0	97%
Falcone	1996	95	1	1	0	1	0	100%
Gabram	1989	126	1	1	0	0	0	93%
Garner	1999	34	1	0	0	1	0	100%
Gerich	1998	381	1	0	0	1	0	99%
Ma	1998	210	1	0	0	1	0	97%
Ma	1998	63	1	0	0	1	0	95%
Ma	1998	54	1	0	0	1	0	78%
Murphy-Macabobby	1992	119	1	0	0	1	0	100%
O'Brien	1988	70	1	1	0	1	0	96%
Rose	1994	100	1	1	0	0	0	73%
Rose	1994	100	1	1	0	0	0	96%
Sing	1998	83	1	0	0	1	0	99%
Slater	1998	314	1	0	0	0	0	97%
Thomas	1999	706	1	1	0	1	0	98%
Vilke	1994	538	1	1	0	1	0	95%
Xeropotamos	1993	143	1	0	0	1	0	100%
Salvino	1993	1240	1	0	0	1	0	100%
		4989	**19**	**9**	**2**	**16**	**0**	**97.3%**

OTI, orotracheal intubation; NTI, nasotracheal intubation; ETI, endotracheal intubation; Cric, cricothyrostomy; Trach, tracheostomy

Table 20. Overall Tracheal Intubation Success Rate with Multiple Procedures -- Emergency Department Studies (n=3)

Author	Year	Patients	OTI	NTI	ETI	Cric	Trach	Rate
Sakles	1998	610	1	1	0	1	0	100%
Thompson	1982	48	1	1	0	1	0	100%
Eggen	1993	26	1	1	0	0	1	100%
		684	**3**	**3**	**0**	**2**	**1**	**100%**

OTI, orotracheal intubation; NTI, nasotracheal intubation; ETI, endotracheal intubation; Cric, cricothyrostomy; Trach, tracheostomy

Table 21. Overall Tracheal Intubation Success Rate with Multiple Procedures -- EMS Ground Crew Studies (n=3)

Author	Year	Patients		OTI	NTI	ETI	Cric	Trach	Rate
Cwinn	1987	35	31	1	1	0	0	0	89%
Jacobson	1996	509	509	0	0	1	1	0	100%
Wayne	1999	1657	1594	1	0	0	1	0	96%
		2201	**2134**	**2**	**1**	**1**	**2**	**0**	**96.7%**

OTI, orotracheal intubation; NTI, nasotracheal intubation; ETI, endotracheal intubation; Cric, cricothyrostomy; Trach, tracheostomy

Table 22. Overall Tracheal Intubation Success Rate with Multiple Procedures -- Trauma Center Studies (23 groups; 20 studies)

Author	Year	Patients	OTI	NTI	ETI	Cric	Trach	Rate
Hawkins	1995	593	0	0	1	1	1	100%
Ligier	1991	31	1	1	0	1	0	100%
Grover	1979	6	1	0	0	0	1	100%
Redan	1991	100	1	1	0	1	0	100%
Criswell	1994	73	1	0	0	1	0	100%
Holley	1989	133	1	1	0	0	0	100%
Redan	1991	7	1	1	0	0	0	100%
Rhee	1990	21	1	1	0	1	0	100%
Dunham	1989	1158	1	0	0	1	0	100%
Ligier	1991	66	1	1	0	1	1	100%
McBrien	1992	29	1	0	0	0	0	100%
Norwood	1994	229	1	0	0	1	0	100%
Rhee	1990	237	1	1	0	1	0	100%
Rotondo	1993	198	1	0	0	1	0	100%
Vijayakumar	1998	160	1	1	0	1	0	100%
Dolin	1992	35	1	0	0	1	0	100%
Grover	1979	8	1	0	0	0	1	100%
Gussack	1988	18	1	0	0	0	1	100%
Herrin	1979	87	1	1	0	0	1	100%
Levy	1997	12	1	0	0	0	1	100%
Mandavia	2000	58	1	0	0	0	1	100%
Reece	1988	35	0	0	1	0	1	95%
Shearer	1993	107	1	1	0	0	1	99%
		3401	**21**	**10**	**2**	**12**	**10**	**99.9%**

OTI, orotracheal intubation; NTI, nasotracheal intubation; ETI, endotracheal intubation; Cric, cricothyrostomy; Trach, tracheostomy

Table 23. Percent Patients Intubated Prehospital -- (data available for prehospital and TC arrival intubations)

Author	Year	Setting	Scenario	Total Patients	Prehospital Intubations	Percent
Cameron	1993	AR/TC	Div	67	35	52%
Hsiao	1993	GR/TC	Cog	60	17	28%
Eckstein	2000	GR/TC	Div	496	94	19%
Karch	1996	GR/TC	Div	283	59	21%
Oswalt	1992	GR/TC	Div	44	18	41%
Rosen	1997	GR/TC	MFI	82	60	73%
				1032	**283**	**27.4%**

AR, aeromedical; GR, ground EMS; TC, trauma center;
Cog, patients with severe cognitive impairment (GCS $\leq$8); Div, diverse trauma patient scenarios; MFI, maxillofacial injury

Table 24. Severe Brain Injury Patients Managed by Prehospital Crews -- Percent Intubated Prehospital

Author	Year	Setting	Total Patients	# Intubated	% Intubated
Murray	2000	GR	852	81	10%
Winchell	1997	GR	1092	568	52%
Boswell	1995	AR	353	268	76%
Winchell	1997	AR	502	432	86%
Rhee	1994	AR	106	106	100%
Rhee	1994	AR	77	77	100%
			2982	**1532**	

AR, aeromedical; GR, ground EMS

Table 25. Success Intubation Rates for Patients Receiving Cricothyrostomy

Author	Year	Setting	Scenario	Attempts	Successes	Percent
Boyle	1993	AR	Div	69	68	99
Gerich	1998	AR	Div	8	8	100
Miklus	1989	AR	Div	20	20	100
Murphy-Macabobby	1992	AR	Div	4	4	100
Nugent	1991	AR	Div	55	53	96
Syverud	1988	AR	Div	1	1	100
Thomas	1999	AR	Div	10	9	90
Xeropotamos	1993	AR	Div	11	11	100
Salvino	1993	AR/TC	Div	30	30	100
Fortune	1997	GR	Div	56	50	89
Jacobson	1996	GR	Div	50	48	96
Leibovici	1997	GR	Div	29	26	90
Spaite	1990	GR	Div	16	14	88
Hawkins	1995	GR/TC	Div	66	65	98
all studies				**425**	**407**	**95.8%**

AR, aeromedical; GR, ground EMS; TC, trauma center

Div, diverse trauma patient scenarios

Table 26. Complication Rates for Patients Receiving Cricothyrostomy

Author	Year	Setting	Scenario	Patients	Complications	Percent
Boyle	1993	AR	Div	68	5	7
Gerich	1998	AR	Div	8	0	0
Miklus	1989	AR	Div	20	0	0
Murphy-Macabobby	1992	AR	Div	4	0	0
Nugent	1991	AR	Div	53	7	13
Xeropotamos	1993	AR	Div	11	0	0
Salvino	1993	AR/TC	Div	30	0	0
Erlandson	1989	ED	Div	77	23	30
McGill	1982	ED	Div	38	12	32
Sakles	1998	ED	Div	7	0	0
Fortune	1997	GR	Div	50	2	4
Jacobson	1996	GR	Div	48	0	0
Leibovici	1997	GR	Div	26	0	0
Spaite	1990	GR	Div	14	0	0
Hawkins	1995	GR/TC	Div	65	2	3
Criswell	1994	TC	CSI	2	0	0
Rhee	1990	TC	CSI	2	0	0
Talucci	1988	TC	Div	3	0	0
Dolin	1992	TC	MFI	2	0	0
Wright	1992	AR/TC	CSI	2	0	0
				530	**51**	**9.6%**

AR, aeromedical; ED, emergency department; GR, ground EMS; TC, trauma center; CSI, cervical spine injury; Div, diverse trauma patient scenarios; MFI, maxillofacial injury

Table 27. Trauma Patients Managed with Emergency Tracheostomy

Author	Year	Setting	Scenario	Attempts	Success	Complications
Grover	1979	TC	Ch	.	1	.
Ligier	1991	TC	Div	1	1	.
Hawkins	1995	GR/TC	Div	.	2	.
Trimble	1986	TC	MFI	1	1	0
Eggen	1993	ED	Nk	13	13	0
Edwards	1987	TC	Nk	.	5	1
Grewal	1995	TC	Nk	15	15	.
Grover	1979	TC	Nk	.	1	.
Gussack	1988	TC	Nk	.	6	0
Herrin	1979	TC	Nk	.	15	.
Kelly	1985	TC	Nk	.	22	.
Levy	1997	TC	Nk	.	4	.
Mandavia	2000	TC	Nk	2	2	0
Reece	1988	TC	Nk	31	31	.
Shearer	1993	TC	Nk	8	7	.
Sofferman	1981	TC	Nk	4	3	.
Lambert	1976	TC	Nk	.	6	.
					135	

AR, aeromedical; ED, emergency department; GR, ground EMS; TC, trauma center; Ch, chest injury; Div, diverse trauma patient scenarios; MFI, maxillofacial injury; Nk, severe neck injury

Table 28. Patients Intubated with Combitube

Author	Year	Setting	Scenario	ISS	GCS	Mortality	% Arrest
Ochs	2000	GR	Arr	.	3	.	100
Blostein	1998	AR	Div	25	3	30	10
Wayne	1999	GR	Div	.	.	.	.
Eichinger	1992	ED	MFI	.	3	.	.
Wagner	1995	GR	Smk	.	.	100	.
Davis	2001	GR	Cog		3		

Author	Year	Attempts	Success	% Success	Complications
Ochs	2000	14	11	79	0
Blostein	1998	10	10	100	0
Wayne	1999	.	9		.
Eichinger	1992	1	1	100	0
Wagner	1995	1	1	100	0
Davis	2001	18	17	94	.
		44	**49**		

AR, aeromedical; ED, emergency department; GR, ground EMS;
Arr, cardiac arrest; Cog, patients with severe cognitive impairment (GCS $\leq$8); Div, diverse trauma patient scenarios; MFI, maxillofacial injury; Smk, smoke inhalation

Table 29. Patients Intubated with LMA

Author	Year	Setting	Scenario	GCS	Mortality	% Arrest	Patients	Complications
Aye	1995	ED	Ch	.	100	.	1	0
Greene	1992	GR	Cog	3	100	.	2	0
McNamara	1996	TC	CSI	3	.	.	1	0
Myles	1994	TC	MFI	3	.	.	1	0
							5	**0**

GCS, Glasgow coma score; ED, emergency department; GR, ground EMS crew; TC, trauma center; Ch, severe chest injury; Cog, severe cognitive impairment (GCS $\leq$ 8); CSI, cervical spine injury; MFI, maxillofacial injury

Table 30. Patients Intubated with Intubating-LMA

Author	Year	Setting	Scenario	GCS	Patients	Complications
Wakeling	1999	TC	COG	3	1	0
Schuschnig	1999	TC	CSI	3	2	0
					3	**0**

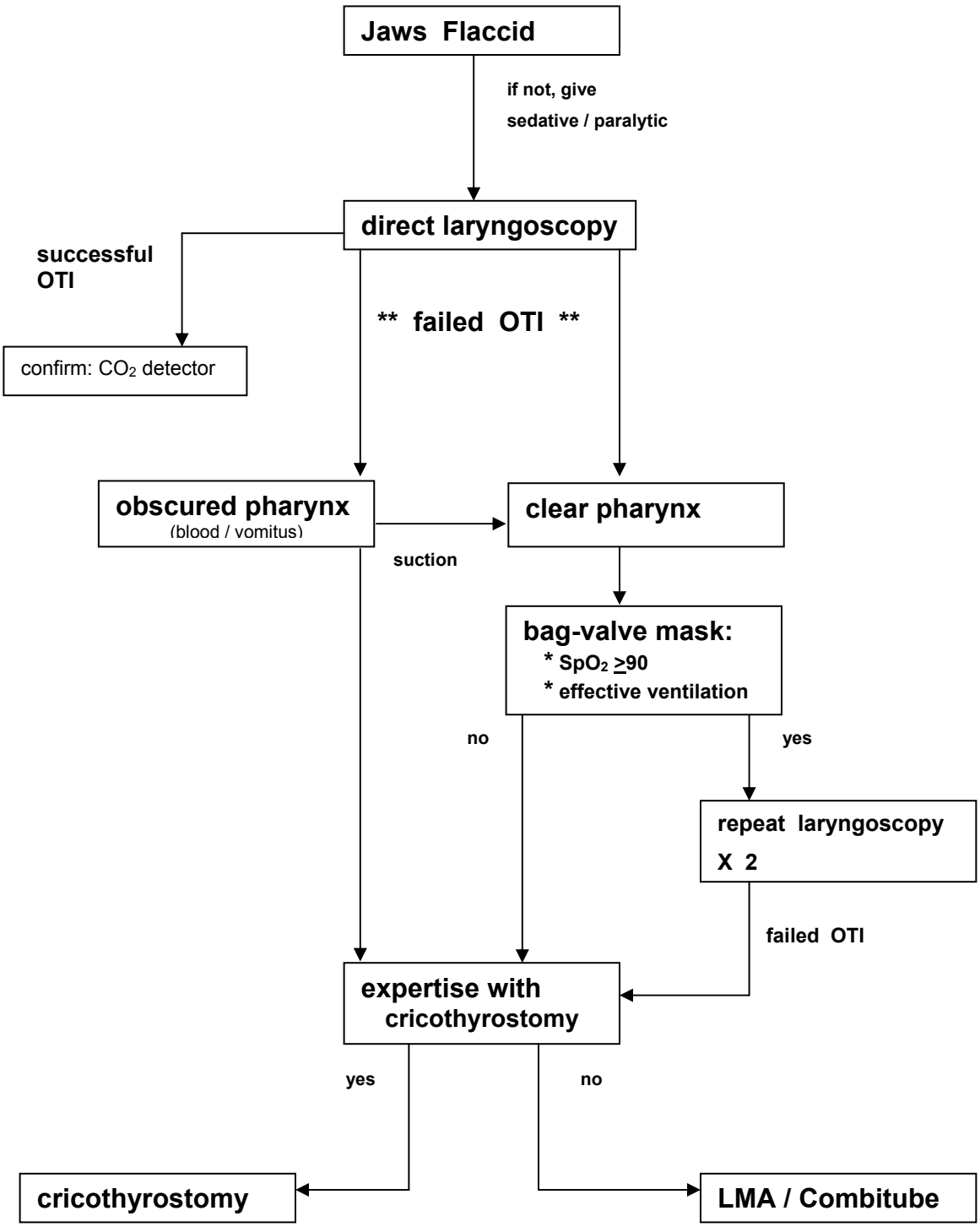
ED, emergency department; GR, ground EMS; TC, trauma center;
Ch, chest injury; Cog, patients with severe cognitive impairment (GCS ≤8); CSI, cervical spine injury; MFI, maxillofacial injury

Reference Numbers for Table Citations

Author	Year	Ref. #	Author	Year	Ref #
Aye	1995	254	**Gussack**	1988	57
Barone	1986	183	**Hartmann**	1985	111
Baxt	1987	72	**Hawkins**	1995	67
Blostein	1998	31	**Herrin**	1979	119
Boswell	1995	27	**Hicks**	1994	198
Boyle	1993	61	**Holley**	1989	239
Cameron	1993	82	**Hsiao**	1993	42
Copass	1984	35	**Jacobson**	1996	28
Criswell	1994	88	**Karch**	1996	46
Cwinn	1987	78	**Kelly**	1985	114
Davis	2001	240	**Koenig**	1992	233
Deo	1994	235	**Kollmorgen**	1994	65
Dolin	1989	145	**Lambert**	1976	120
Dunham	1989	81	**Leibovici**	1997	47
Eckstein	2000	33	**Levy**	1997	113
Edwards	1987	116	**Ligier**	1991	40
Eggen	1993	109	**Ma**	1998	228
Eichinger	1992	252	**Mandavia**	2000	68
Erlandson	1989	59	**McBrien**	1992	19
Falcone	1996	45	**McGill**	1982	55
Fischer	1984	70	**McNamara**	1996	256
Flancbaum	1986	242	**Meschino**	1992	41
Fortune	1997	29	**Miklus**	1989	15
Gabram	1989	38	**Mlinek**	1990	244
Garner	1999	75	**Muckart**	1997	234
Gentleman	1992	199	**Mulder**	1975	245
Gerich	1998	74	**Murphy-Macabboby**	1992	144
Greene	1992	255	**Murray**	2000	69
Grewal	1995	115	**Myles**	1994	241
Grover	1979	118	**Neal**	1996	246

Author	Year	Ref. #	Author	Year	Ref #
Norwood	1994	24	**Sloane**	2000	34
Nugent	1991	60	**Sofferman**	1981	117
O'Brien	1988	36	**Spaite**	1990	16
O'Brien	1989	243	**Syverud**	1988	37
Ochs	2000	51	**Talucci**	1988	14
Oswalt	1992	20	**Tayal**	1999	229
Plewa	1997	236	**Thomas**	1999	50
Redan	1991	18	**Thompson**	1982	230
Reece	1988	58	**Trimble**	1986	251
Rhee	1990	39	**Trupka**	1994	25
Rhee	1994	44	**Vicario**	1983	159
Rose	1994	73	**Vijayakumar**	1998	49
Rosen	1997	128	**Vilke**	1994	26
Rotondo	1993	80	**Wagner**	1995	253
Sakles	1998	237	**Wakeling**	1999	257
Salvino	1993	22	**Wang**	2000	231
Schuschnig	1999	258	**Wayne**	1999	232
Shatney	1995	89	**Winchell**	1997	30
Shearer	1993	64	**Wright**	1992	21
Sing	1998	32	**Xeropotamos**	1993	23
Slater	1998	48			

Procedural Options for Trauma Patients Needing Emergency Tracheal Intubation



Laryngotracheal injury (severe neck injury): partial airway obstruction → OTI; severe airway obstruction → surgical airway (cricothyrostomy / tracheostomy)