# *Immediate Care of the Wounded*

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# Airway

*And when Elisha was come into the house, behold, the child was dead, and laid upon his bed. And he went up, and lay upon the child, and put his mouth upon his mouth…and the flesh of the child waxed warm…and the child opened his eyes*

II Kings Chapter 4 verses 32-35, King James Version

*"Of all the surgical operations which are performed in man for the preservation of life by the physician, I have always judged to be the foremost that by which man is recalled from a quick death to a sudden repossession of life, a feat which raises to the level of Aesculapius; the operation is the opening of the asperia arteria [trachea], by which patients, from a condition of almost suffocating obstruction to respiration, suddenly regain consciousness, and draw again into their heart and lungs that vital ether the air, so necessary to life, and again resume an existence which had been all but annihilated."* [1]

Hieronymus Fabricius 1537–1619
Italian Anatomist and Surgeon

*"Wounds of the face, when they do not implicate the brain, are not usually of a serious character."*

Dr. Julian John Chisolm, Confederate Surgeon
Manual of Military Surgery, Chapter 8 *Wounds of the Face* p. 268

*The mental image suggested by the term "gunshot wound of the face and jaws" invariably induces an emotion of sympathy, pity, or out and out revulsion. While numbering few in the total of war casualties, they demand and deserve every conceivable effort in the matter of medical care*[2]

"Maxillo-Facial Injuries" by Major Henry B. Clark in
Forward Surgery of the Severely Wounded
(A History of the Activities of the 2nd Auxiliary Surgical Group)
World War II

## *Introduction*

Having a patent airway is an essential prerequisite to life. Of this, there is no dispute. All textbooks on pre-hospital care identify airway management as the preeminent skill in resuscitation because humans can only briefly tolerate anoxia; if there is no airway, there is no life. Although there is no argument about these fundamental facts, almost every other aspect of pre-hospital airway management has become disputable, particularly in a combat environment. The fundamental questions in these debates are not whether airway management is important, but rather (1) how likely is airway obstruction, which is amenable to and requires medical correction, to be a problem in a pre-hospital military environment and, (2) after establishing that airway management must be done,

- When should it be done;
- Who should do it;
- How should it be done; and
- What equipment or medications, if any, should be used?

How likely is airway obstruction to be a medically correctable problem in a population of military patients; more specifically how likely is it to be a problem in a population of combat casualties? Although basic airway management should be part of every pre-hospital care provider's array of skills, if airway obstruction is an extremely rare medical problem in the population of interest (living combat casualties), teaching intubation may result in more problems then benefits -- especially if done incorrectly or when not indicated.

## *History of Airway Management*

For most of the history of man conditions that cause complete airway obstruction have resulted in death, there being little that those in the medical professions could do to change this result. This does not mean that nothing has tried, occasionally with some success. Most of the efforts have been surgical but, particularly in more recent history, not all. Stock, in his "A Short History of the Development of the Tracheostomy",[4] noted that the Babylonian Talmud (AD 352-427) makes reference to a case of swelling of the throat (possibly referring to a peritonsilar abscess) saying that while a transverse division of the trachea will be fatal, a longitudinal section will not; suggesting that surgery had been tried for this condition, perhaps with some success. For some cases of cynanche [infection/inflammation of the upper airway with associated difficulty breathing] surgical intervention has been suggested and even tried since not long after the death of Christ. Around 117 AD Antyllus wrote that,

> *"In cases of cynanche we entirely disapprove of the operation [tracheostomy] because the incision is wholly unavailing when all the arteries [the whole of the trachea and bronchi] and the lungs are affected; but inflammation about the mouth and palate, and in cases of indurated tonsils, which obstruct the mouth of the windpipe and the trachea is unaffected, it will be proper to have recourse to pharyngotomy, in order to avoid the risk of suffocation."*

Thus, it is clear that tracheostomy was being performed by western surgeons some 2,000 years ago.[4] In 1546 Antonio Musa Brasavalo published the first account of a tracheostomy actually being done,[5] stating that, "When there is no other possibility, in angina, of admitting air to the heart, we must incise the larynx below the abscess." Fabricius (1537-1619) described tracheostomy in detail, in glowing terms (see opening quote), but he never performed the operation himself.[1]
By the early 1600's, according to Stock, tracheostomy appears to have been considered an acceptable procedure for the treatment of upper airway obstruction. Sanctorious (1561-1636) performed tracheostomy with a trocar and recorded leaving the cannula in place for three days. Nicolas Habicot performed four successful tracheostomies in 1620; one on a 14 year old boy who had swallowed a bag of gold coins to prevent their theft whereupon the bag became lodged in the esophagus causing partial airway obstruction.[6]

Marco Aurelio Severino (1580 – 1656), a well-known anatomist and famous surgeon, performed tracheotomy several times during the Naples diphtheria epidemic, this procedure having been previously described and recommended by Guidi, Fabricius, and Sanctorius.[7] Luckhaupt, in the German Journal, *Laryngologie, Rhinologie, Otologiel,*[8] noted that while the Arabian doctor Avicenna (980-1037) described the first orotracheal intubation for the treatment of dsypnea, the real beginning of endotracheal intubation begins with this procedure being performed by obstetricians and lifesavers in the 18th century.

In 1884, after four years of experimentation, intubation was first successfully performed by Joseph O'Dwyer (1841-98).[7] Intubation of the larynx for croup was first performed by Eugene Bouchut (1856), who inserted a small thimble-like tube in the larynx, but results were so poor that it failed to replace tracheotomy. In 1880 McEwen is documented to have preoperatively intubated a patient to prevent the aspiration of blood. Later, in 1900, Franz Kuhn first performed routine intubation to keep the airway clear during narcosis.[8]

In 1950, in the first volume of the Armed Forces Medical Journal, Tarrow and Knight describe the manufacture and use of the modern, long-cuff, endotracheal tube.[9]

During the Civil War, as a new way of treating neck injuries that obstructed the airway, surgeons performed tracheostomies, which were then referred to as bronchostomies. As reported in Bollet's book, "Civil War Medicine, Challenges and Triumphs", they even left the tube in for long periods if necessary.[10] Bollet records that twenty of these procedures were performed with seven survivors. Six of the twenty were done to treat patients with gunshot wounds and the other fourteen to treat patients with diseases such as diphtheria and abscesses which threatened to occlude the airway. In at least one instance a silver tube was inserted as a tracheostomy tube that was later replaced by a "double fenestrated cannula" which the wounded soldier continued to wear six months after his initial injury.

### *Frequency of Airway Obstruction in Civilian Population*

In a 6-month long French survey of out-of-hospital emergency intubations in the suburbs of Paris,[11] there were 691 out-of-hospital endotracheal intubations; the most common indication for this procedure being cardiac arrest (333/691 [48.2%]). Among patients without cardiac arrest, the

most common indication was unconsciousness (198/358 [55.3%]). Only 9.3% (64/691) of intubated patients were trauma patients; of these, 22 (3.2%) had multiple injuries, 31 (4.5%) had head injuries and 11 (1.6%) had burns.

Although it is unclear from the report whether any of the patients with multiple trauma also had head trauma (a common indication for intubation in trauma patients), it is clear that at least half of all pre-hospital intubated trauma patients were intubated due to head trauma (and it is almost certain that nearly all of these had sustained blunt, not penetrating trauma).

### *Frequency of Airway Obstruction in Combat*

What is the incidence of potentially survivable airway obstruction in combat trauma patients? Estimates of the number of combat casualties needing airway management (generally defined as those needing either intubation or a surgical airway) are based upon data obtained from medical treatment facilities, not pre-hospital data, which is entirely unavailable. This likely represents only a small portion of all casualties experiencing acute posttraumatic airway obstruction, however, because such casualties have, in the great majority of instances, already survived for more than an hour prior to reaching medical care.

As stated by Bellamy in "Combat Casualty Care Guidelines -- Operation Desert Storm"[12] in the Vietnam Wounding Data Munitions Effectiveness Team (WDMET) data[13], only 1.3% of combat casualties who arrived at medical facilities required emergency airway management; and only about half of these casualties (0.7% of the total) had sustained traumatic airway injury. Another 0.6% required airway control for ventilation due to severe neurological injury.

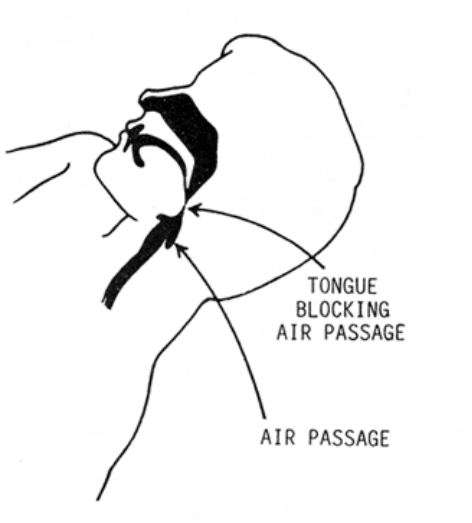
The incidence of casualties needing airway management upon arrival at a medical treatment facility in Vietnam (0.6%) is quite similar to that occurring during Operation Desert Storm in 1990. Burkle et al.[14] reported that 2 (1.2%) of 164 combat casualties admitted to the Khanjar Navy-Marine Trauma Center had an airway obstruction that required tracheotomy. It should be noted that these patients arrived alive (probably after a lengthy evacuation) without any pre-hospital surgical airway having been established, so the degree of urgency of the airway problem is unclear.

Bailey, in his World War II era text, "Surgery of Modern Warfare,"[15] noted that, "Wounds of the larynx are less commonly seen than are those of the jaws and pharynx, because of their greater mortality" and he notes that injuries to the cervical spine and great vessels of the neck are common and rapid causes of death in casualties with penetrating neck injuries.[15(p.808)][Chapter LXXI Wounds of the Air Passages and Air Sinuses – Larynx, Penetrating Wounds].

As is the case with other types of injuries [see discussion about the Soviet incidence of cervical spine injuries during WII in the section on "Disability"] the incidence of airway injuries in combat appears to be affected by the type of combat. In World War II it was noted that, "During the hedgerow fighting in Normandy, there was an unusually high incidence of maxillofacial injuries resulting from the close type of combat and the necessity for the men to expose their heads to see the enemy. These wounds were predominantly caused by small arms fire and were characterized by being exceedingly severe and

not being associated with wounds elsewhere in the body."[16]

It is also likely that the incidence of airway injuries in combat is affected by both the type of armaments used and the frequency of body armor use. Weapons that cause burn injury, for example, might create more casualties with airway injury that is not immediately fatal (caused by progressive swelling) and thus might be amenable to medical intervention. Likewise body armor, by reducing the number of casualties killed outright by fatal wounds to the thorax and abdomen, might result in an increase in the number of airway injured casualties who survive initial injury.




Airway Obstruction by Tongue, from United States Naval Hospital Corpsman 3 & 2 Training Manual NAVEDTRA 10669-C June 1989

A large civilian series of patients with facial trauma[17] found the causes of airway obstruction in trauma patients to be the following:

(1) obstruction by foreign body (e.g. vomitus)
(2) obstruction by soft tissue (e.g. tongue), hematoma, or avulsed parts
(3) disruption of the trachea

Most of these patients had mid-face fractures caused by blunt trauma and the obstruction was caused by posterior displacement of the midface. Only 17 of 1,025 facial fracture patients (1.7%) developed airway compromise that required emergency airway procedures. The authors of this study found that the rate of endotracheal intubation in patients with maxillofacial injury ranged from 2% to 6%. Because roughly 17% of seriously traumatized patients have maxillofacial trauma[17] this means that somewhere between 0.4% and 1% of all civilian trauma patients, most having blunt injury, require intubation for airway problems resulting from maxillofacial trauma.

It is worth noting that in this study the number of trauma patients requiring airway intervention for maxillofacial trauma is quite similar to that described earlier in military series despite the differences in patient populations. This is somewhat surprising because it would seem that patients sustaining blunt trauma to the head and neck would be more likely to present alive and needing urgent airway management than would those having sustained penetrating trauma.

The other major indication for intubation of civilian trauma patients is inability to protect the airway, which occurs in severely head-injured or intoxicated patients. Unfortunately, these statistics from a civilian population cannot be extrapolated to a population of combat trauma patients because, as noted by Smith and Bellamy, "Combat casualties do not have the same propensity for blunt trauma, cervical spine injury, upper airway problems, etc., as do civilian trauma victims."[18]

The specific nature of combat-related airway injury was elucidated by Rehwald[19]

(in the Textbook of Military Medicine Part IV, Surgical Combat Casualty Care: Anesthesia and Perioperative Care of the Combat Casualty, Chapter 3 Airway Management by Hecker and Kingsley[20(p.57)]). Using German data from World War II, Rehwald reported the major causes of asphyxiation associated with injury to the face and jaw as obstruction by the tongue (40%), oropharyngeal tissue (29%), or soft tissue (5%), tracheal compression (23%), and aspiration of blood and vomitus (3%).[19]

Fortunately, among those surviving long enough to reach hospital level care the mortality rate in maxillofacial wounds tends to be low. In Fifth U.S. Army hospitals during World War II, there were only 6 deaths from this cause described in 1,450 battle casualty deaths.[21]

### *Indications for Airway Management*
### *Management at Point of Wounding*

If airway management is necessary it usually needs to be accomplished within a few minutes of wounding if the casualty is to survive. This fact has significant implications in the pre-hospital combat casualty care airway management debate. Combat casualties who develop an airway obstruction either immediately after or within a few minutes of wounding will only survive if they themselves, or someone nearby who can reach them immediately, can clear their airway.

In general, airway clearing need not be part of self-care training provided to all combatants because individuals whose condition permits them to do so will reflexively position themselves to allow the most unobstructed breathing and to remove blood and secretions from the airway. However, at a conference conducted at the end of the Korean War, it was suggested that instruction be provided to maxillofacial-wounded casualties as to "how to hold [their] head or how to lie on the litter" because this may be lifesaving during the period of evacuation. It was also suggested that "With bleeding about the nose and mouth [such patients] should be instructed to lie in a manner that will allow the blood to drain to the exterior and not pass into the throat and cause aspiration and suffocation."[22]

If maxillofacial wounded casualties are unable to clear their own airway, then someone else must perform the necessary airway management procedure(s) or they will die quickly. The number of casualties who die within minutes of airway obstruction is not known because it is difficult to determine the precise cause of death at autopsy, particularly in those who have sustained multiple injuries. Although it is impossible to determine from the WDMET data the exact number of soldiers who died on the battlefield in Vietnam due to acute airway obstruction prior to medical intervention, autopsy results suggest that this occurrence was uncommon.[(Bellamy RF, Colonel, Medical Corps, US Army. Personal Communication, March 1995)][20(p. 56)] Unfortunately, autopsy data fail to reveal whether these casualties died from airway obstruction or with airway obstruction (exsanguination and fatal neurologic injury being common in patients with severe wounds to the head and/or neck, as was noted earlier).

### *Prophylactic Airway Management*

Of course, not all airway obstruction occurs at or near the time of injury. There are instances, such as with inhalation injury or an expanding hematoma in the neck, where the airway should be managed well before there is any significant obstruction. There are also instances, such

as when a casualty becomes progressively less able to maintain his or her own airway (e.g. as with decreasing level of consciousness) where it is necessary for a care provider to manage the casualty's airway at a time considerably past the time of initial injury.

This type of patient is not uncommon in civilian pre-hospital care where closed head injury (expanding subdural or epidural hematoma) and drug and/or alcohol intoxication is usually the cause. Neither of these conditions, however, is common in battlefield casualties. Another category of patients needing airway management in the civilian pre-hospital setting includes those with disease processes such as severe asthma, cardiac problems, or severe pneumonia, which are rarely found in the pre-hospital battlefield patient population. It is worth noting, however, that individuals with a prior history of childhood asthma are no longer precluded from enlistment so the frequency of respiratory emergencies from this cause is likely to rise in the future.

### *Responsibility for Airway Management at Point of Wounding*

As described in the Anesthesia volume of this series,

> *Many of the battle casualties who require immediate airway intervention will not survive to be evacuated from the site of injury to the field hospital level without first receiving airway control. For these casualties, airway intervention must take place in the first or second echelons of care…. Therefore, medics, physician assistants, and physicians providing care at the first and second echelons must be able to provide early airway management.* [20(p.57)]

Because airway obstruction must be alleviated within minutes or the patient will not survive, moving an airway obstructed patient to someone who can clear his or her airway is not an effective option in most instances due to the associated inherent time delay. From a training perspective, this means that better training in basic airway management for every soldier, during basic training and within the combat lifesaver program, is more likely to save lives than will advanced airway management training for any higher, and less immediately available, levels of medical care (See surgical airway section, below, for a discussion of training considerations for advanced airway procedures).

### *Decision Making in Airway Management*

It is reasonable to question the efficacy of the standard civilian approach to pre-hospital airway management especially if it is to be applied to a population of combat casualties. Every intervention has consequences. Actions taken that might provide benefit in one situation might cause more harm than benefit in another. Airway management of the potentially cervical-spine injured patient is an example where the civilian approach may be inappropriate in a combat setting.

Standard Advanced Trauma Life Support (ATLS)[23] and Emergency Medical Technician (EMT) training emphasizes that because patients with head and neck injuries (i.e., injuries above the clavicle) have a higher probability of unstable cervical spine injury, the cervical spine must be stabilized in all such patients. This means that they are to be placed on a backboard, a rigid cervical collar applied, and their heads and bodies strapped and taped to the backboard. The airway of such "pack-

aged" patients is put at risk in the following ways:

- Being forcibly held in a supine position makes the patient extremely dependent upon someone else to clear his or her airway in the event that vomitus, blood, tissue, or other debris cause obstruction;
- Obstruction of the airway by the tongue is much more likely in the supine position
- The cervical collar, even if properly applied, and it often is not (and improperly applied may actually physically obstruct the airway), forces the mouth closed.

Despite these concerns, because blunt trauma is much more likely than penetrating trauma to produce an unstable cervical spine[24], and because there are usually adequate medical personnel with appropriate equipment to keep the airway clear, this is probably, nonetheless, appropriate for the majority of civilian trauma patients. Because none of these circumstances are likely to be present in forward combat areas, however, such management carries substantial risk with little hope of benefit. When the possibility of an unstable cervical spine is present in a combat casualty (e.g. a motor vehicle accident, fall from a height) and when medical vigilance can be provided and sustained to ensure that the airway remains clear, Advanced Trauma Life Support guidelines for civilian management of possible cervical spine injury remain reasonable and appropriate in the combat setting. (A detailed discussion of patient packaging for suspected spinal injuries appears in a following section on "Disability")

Unfortunately simple and basic lifesaving airway management techniques are often not well emphasized or taught in pre-hospital medical education. The very fact that they are basic and relatively simple to perform tends to cause healthcare workers to undervalue their importance. For this reason, and others, pre-hospital care providers who are taught more advanced airway skills often go directly to the use of advanced procedures even when more basic techniques would have sufficed if properly performed; occasionally with tragic consequences. The following case provided from civilian EMS literature, is illustrative:[25]

> *A 17 year old girl was an unrestrained passenger of a vehicle that struck a stationary truck. She was eventually found to have sustained a liver laceration, right pulmonary contusion, Le-Forte II/III and mandible fractures, and an acetabular fracture -- a CT of the head revealed no intracranial hemorrhage.*
>
> *Citing instability of "unstable" facial fractures as their justification, the on-scene paramedics elected to intubate the patient [perhaps the patient developed respiratory difficulty when she was placed in a supine position and secured on a backboard for cervical-spine control].*
>
> *Several unsuccessful attempts were made to orally intubate the patient without administration of a paralytic agent. When the aeromedical team arrived they described the patient as "awake, alert, and oriented X 3 with full recall of the accident." Citing again "deformed" and "unstable facial bones" and "respiratory difficulty" the aeromedical team elected to perform rapid sequence intubation of the patient using etomidate and succinylcholine. This despite that fact that there was no documented drop in*

*oxygen saturation and vital signs remained unchanged. Furthermore their notes reflect that the patient had, "A normal mental status, and "clear speech."*

*Endotracheal tube placement was confirmed by appropriate breath sounds [notoriously unreliable under the best of circumstances-- which this was not]. No end-tidal $CO_2$ was recorded. The record then reflects the endotracheal tube became "dislodged" while it was being secured with ground crew assistance. At this point, "multiple" unsuccessful oral intubation attempts were made (no number recorded by the crew).*

*The patient's oxygen saturation fell from 96% to 88% and then to 74% over a period of 8 minutes. Bag-valve-mask ventilation was reportedly difficult so a cricothyrotomy (unsuccessful) was attempted. Cardiac arrest occurred 5 minutes prior to ED arrival.*

*A final pre-hospital attempt at oral intubation was successful. In the emergency department the patient was noted to be in a rhythm of pulseless electrical activity; this was successfully treated with return of spontaneous circulation. Unfortunately in the intensive care unit, multi-system organ failure ensued, brain death was declared; 55 hours after admission life support was withdrawn. Tragically, a trauma review panel concluded that <u>all of the patient's initial injuries were survivable and death resulted from hypoxia</u> due to failed airway interventions.*[25]

### *The Technical Imperative*

In July 1981, Rosen et al. introduced the concept of the "technical imperative," and applied it to pre-hospital care (although this concept actually applies to all levels of care).[26] First, the authors noted the psychological obstacle that exists in emergency medical personnel to inaction;

> *…there is a pervasive theme [in emergency care]…one of action orientation, that is, of specific technical intervention…. [B]efore addressing the individual procedures, the psychological basis underlying the performance of technical acts must [should] be considered.…[W]e select for, and demand, an aggressive, action-oriented psychological profile in our personnel. The consequence of this is that the hardest task for any good paramedic, nurse, or emergency physician to perform is inaction.*

Next, they described the technical imperative as follows:

> *If a procedure is taught, it will be used with a frequency greater than its indications. [Further], every procedure…has a cost that must be assessed as a complex therapeutic ratio, the deficit to the patient produced by not performing the procedure versus the deficit produced by performing the procedure "improperly" or performing it properly but unnecessarily.*

Even when medical procedures are properly performed and done only for valid, indicated, reasons, there can be life-threatening complications. Airway injury during airway management even in the best of circumstances, such as endotracheal intubation performed by anesthesiologists/anesthetists during general anes-

thesia, is a significant source of morbidity for patients.[27] Although most of these injuries are not life-threatening, some, such as pharyngeal and esophageal injury, can be. Esophageal injuries are more severe than all other types of airway injury combined and represent a significant portion of intubation-induced mortality.[28-31]

### *Airway Management Procedures*

The ideal approach to emergent airway management of a combat casualty in a given set of circumstances depends upon the following:

- Degree of patient acuity
- Level of training and experience of the pre-hospital care provider(s),
- Tactical and environmental situation,
- Mode and distance of evacuation,
- Number of other casualties present
- Availability of medical personnel to manage the patient after the definitive airway management procedure has been performed.

When managing airway problems in combat environments pre-hospital personnel should consider using the least invasive techniques first, and refrain from using advanced procedures until they have balanced the inherent risks against the anticipated benefit. The least invasive procedures such as proper positioning, maneuvers such as the head-tilt or jaw-thrust, and clearing of the airway of secretions or debris, carry the least risk to the patient and can be most easily taught and sustained. For the majority of patients needing airway management in the pre-hospital combat environment, these procedures are usually adequate.

### *Basic Airway Management*

As described by Bailey in World War II, in managing patients with maxillofacial wounds, "The immediate aim is to save the life of the patient." This means maintaining the airway, controlling hemorrhage, and preventing blood and other things from entering the trachea and causing airway obstruction.[15(p.811)] As noted above, these tasks can usually be effectively achieved by timely and effective application of a few simple, basic, procedures.

### *Body Position*

During World War II the following guidance regarding proper litter evacuation of casualties was provided by the Surgical Consultant in the European Theater of Operations:

> *In the litter evacuation of fresh maxillofacial casualties, adequate attention occasionally has not been paid to the proper position for such cases. Improper position may result in fatality during evacuation. Instructions on this matter should be provided all personnel handling fresh casualties. Severe cases should be arranged in a prone position on the litter with the head supported by blankets. Such position gives the greatest assurance that the airway will be maintained and provides against the danger of aspiration of blood and oral secretions.*[32]

Also in World War II, Henry K. Beecher noted that among "common but grave errors" was the "transporting of patients in a face-up position instead of face-down, when they have pharyngeal wounds."[33] And the WWII history of the 2nd Auxiliary Surgical Group notes that "Maintenance of a clear respiratory tract may be accom-

plished by…extension of the tongue, and by postural drainage."[34] Earlier, in the Spanish Civil War (1939), Douglas Jolly, a British military surgeon, noted that following emergent treatment, patients who have sustained buccal wounds should be:

1) Placed in the prone position with a folded coat or haversack under the chest and their heads turned to the side
2) Under continuous surveillance by an orderly during evacuation and in the event that hemorrhage occurs from the face or pharynx
3) Kept by the orderly in the prone position and the orderly must swab the pharynx to prevent aspiration of blood into the glottis.[35]

Supporting these earlier observations is a recent study[36, 37] of poisoned comatose patients that demonstrated that the prone and semi-recumbent (head-down) positions are associated with a reduced incidence of aspiration pneumonia.

In the Anesthesia volume of "The Textbook of Military Medicine", Hecker & Kingsley note that,

> *Casualties with facial lacerations (common in penetrating head trauma) often present with copious bleeding that may contribute to airway obstruction. Relief of obstruction can frequently be obtained with gentle suctioning and if possible, by allowing the casualty to sit forward rather than supine. Gentle forward traction on an unstable, fractured mandible may also relieve simple obstruction."* [20(p. 74)]

As noted above, World War II data indicate that asphyxiation associated with facial and jaw wounds was due to prolapse of the tongue into the pharynx in 40% of cases and to aspiration of blood and vomitus in 3% of cases.[20(p. 57)] Given that some of the other causes of asphyxiation described in these data may have been correctable with simple airway maneuvers and/or patient positioning, it may be surmised that at least half of all cases of death from asphyxiation after maxillofacial trauma may be preventable with basic airway maneuvers and proper patient positioning.

At, and forward of, the Battalion Aid Station or similarly equipped and staffed treatment post, it is difficult to do more than the most basic of procedures so the maxillo-facial wounded casualty should be transported as soon as possible to a better equipped and staffed facility. According to Bailey, "Obvious bleeding points should be controlled…however, if the compression has the effect of increasing the amount of inhaled blood, it must then be decided to allow free external escape, for fear of asphyxiating the patient…If a suction pump is available, its use will be of great benefit in dealing with these complications."[15]

Interviews of paramedics by Karch et al. found that although failure to intubate trauma patients in the field was most common in gagging or combative patients, in nearly a quarter of survivors, inability to intubate was due to blockage of the airway with blood or vomitus.[38]

Even the ATLS course[23], which strongly advocates rapidly obtaining a definitive airway, makes it clear that not all patients with airway trauma require immediate advanced airway management. Even patients who have sustained massive trauma to the upper airway can often be managed, at least initially, using the basic airway management techniques described above. The patient shown below in Fig 1 is such a

patient. Note that this patient is not intubated and does not have a surgical airway. Only suctioning and positioning were used to keep this patient's airway clear in the emergency department.

Frequently, at the point-of-wounding, patients with such injuries have already positioned themselves to optimize their airway and if able to do so will continue to protect their airway unless interfered with by later arriving medical personnel. Sometimes well-intentioned pre-hospital personnel, while attempting to minimize the risk of injury to a potentially unstable cervical spine, will interfere with the patient's efforts to maintain a patent airway, thereby doing more harm than good. Often patients with massive facial trauma do best when allowed to sit up and lean forward, allowing blood, secretions, teeth, and soft tissue to be kept out of the upper airway.

This author personally recalls the case of a civilian patient with blunt facial trauma who developed airway obstruction as a direct result of such well-intentioned cervical spine management. The patient had been struck in the face with a baseball bat fracturing both sides of his mandible and a number of teeth. When EMS arrived the patient was on his hands and knees with blood dripping from his mouth, spitting out teeth and in pain but not in any respiratory distress. EMS personnel, following their guidelines, placed the patient in a supine position, with his cervical spine immobilized, on a backboard. When the patient arrived in the emergency department he was having marked difficulty breathing due to prolapse of his unsupported tongue into the posterior pharynx; this was alleviated with suction and outward digital traction of the jaw. In this instance well-intentioned EMS intervention almost killed the patient.

Figure 1. This man was the victim of an attempted assassination by shotgun blast to the head (turned head at moment shot was fired). The patient was responsive on ED admission. Only suctioning and positioning were used to keep this patient's airway clear in the ED. A surgical airway was placed in an operating room. Patient lost one eye and had his face reconstructed. Photo provided courtesy of Dr. Peter Rhee, military trauma surgeon

Administration of morphine to combatants with facial wounds - It was Maj. Jolly's opinion, during the Spanish Civil War, that morphine must be given early in all such cases, preferably intravenously so as to produce an immediate effect.[35(p.137)] But just a few years later, in World War II, Bailey recommended that morphine be avoided in maxillofacial wounded casualties "owing to its depressing effect on the cough reflex and respiratory centre" because, "the patient's life may depend on his ability to protect his airway by coughing."[15] On this same issue the WWII history of the activities of the 2nd Auxiliary Surgical Group noted that, "Due to mechanical respiratory difficulties in many of these cases it is wise to give morphine sparingly and in no case is it advisable to give more than ¼ grain (15 mg) every four hours."[34] Interestingly today even this smaller amount of morphine is higher than most pre-hospital personnel are comfortable with administering or, in some instances, are allowed to give.

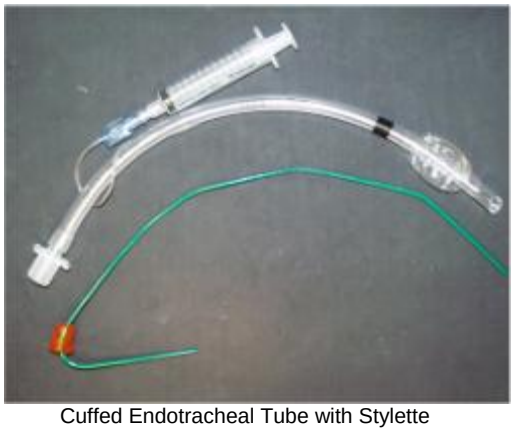
### *Advanced Airway Management*

There is little dispute that when a patient has either significant or impending airway obstruction, establishing a definitive airway with a cuffed tube is ideal. Depending upon the circumstances, this is appropriately accomplished either by endotracheal intubation or by establishment of a surgical airway. The pre-hospital environment is, of course, a less-than-ideal surgical venue, being characterized by varying degrees of chaos; imminent danger; environmental extremes; inadequate lighting; inadequate equipment; and healthcare providers who are either untrained in, or at least relatively inexperienced in, the performance of advanced airway procedures. All of these factors decrease the likelihood of successful performance of definitive airway procedures. Under these circumstances, even if definitive airway management can be successfully accomplished without serious complications, most intubated patients not only are completely dependent upon others for every element of their survival but in the majority of situations they must be continually ventilated. In the pre-hospital combat environment, this creates a difficult, if not impossible, logistical challenge during evacuation to higher levels of care.

### *Indications*

Emergency airway management requiring advanced airway procedures in the setting of trauma is most often indicated in cases of severe head injuries. WDMET data indicate that more than half of the 1.3% of combat casualties requiring emergency airway management had severe head injuries[20(p. 56)] [It should be noted here that Bellamy's "The Nature of Combat Injuries and the Role of ATLS in their Management" and the Anesthesia volume of the Textbook of Military Medicine[20(p.56)] have the incidence of head injuries and traumatic airway injury as an indication of intubation reversed (although both are so close – 0.6% and 0.7% -- that it is probably not a significant error)]. In a 1997study of pre-hospital cricothyrotomies done by physicians in Israel, cricothyrotomies were done on only 3.3% of all patients requiring pre-hospital airway procedures and, of these, roughly two-thirds had sustained penetrating trauma [39] (Israel may be somewhat unique among developed countries because of its disproportionately high percentage of patients sustaining penetrating trauma).

Cricothyrotomies were successfully completed in 26 of the 29 study patients (89.6%), but overall mortality in the study was 55.1%.



Cuffed Endotracheal Tube with Stylette

## *Efficacy*

Unfortunately in many, if not most, cases, if endotracheal intubation can be performed on a severely head injured casualty without the use of paralytic and sedative drugs (i.e., when the patient is unresponsive, flaccid, or has no gag reflex) the likelihood of survival is very low. This means that, in most cases, if intubation is to help save patients with survivable injuries, rapid sequence intubation must be done. Some civilian emergency medical systems authorize paramedics to perform rapid-sequence intubation but a recent study by Dunford et al. [40] raises serious doubts about the safety of this procedure when performed by pre-hospital personnel in an out-of-hospital setting.

In this study the incidence of desaturation and pulse rate reactivity during paramedic rapid sequence intubation in 54 patients with severe head injury (Glasgow Coma Scale ≤8) was determined.[40] Thirty-one (57%) patients experienced desaturation during rapid sequence intubation, with 26 (84%) of the desaturation episodes occurring in patients whose initial $SpO_2$ value was greater than or equal to 90%. Therefore, patients given rapid-sequence intubation experienced more hypoxia, the very condition intubation is intended to prevent, than those managed with basic airway techniques and assisted bag-valve-mask ventilation. The extent and duration of desaturation were significant in several of these cases and six (19%) of the patients experienced marked bradycardia (defined here as a pulse rate of < 50 beats per minute so presumably a heart rate between 50 and 60 was not considered to be "marked").

Perhaps the most unsettling finding of this study is that the paramedics performing the rapid sequence intubation described the procedure as "easy" in 26 (84%) of 31 patients who experienced desaturation. Spaite and Criss[41] note that these findings make the near absence of reported significant complications in other studies of pre-hospital rapid sequence intubation seem implausible; they point out the following:

- The Dunford study, despite being carried out in a busy, metropolitan EMS system with substantial medical oversight and involving experienced paramedics, had a staggering rate of significant desaturation during rapid-sequence intubation, suggesting that an even higher rate could be expected under less optimal circumstances
- The fact that the paramedics assessed the rapid-sequence intubation procedure as "easy" despite the 84% associated morbidity suggests that other EMS studies that rely on self-reporting of com-

plications very likely suffer from significant under-reporting.

In a study of field-intubated trauma patients by Karch et al.,[38] in which roughly one-third had sustained gunshot wound(s), the following findings were noted:

- Intubated gunshot wounded patients were the least likely of all intubated patients to survive to discharge
- All surviving intubated trauma patients had head and/or facial injuries
- No patients with truncal injuries who required intubation survived
- Only slightly more than half of these patients were successfully intubated in the field
- Field intubation was three times more likely to be associated with nosocomial pneumonia than was hospital intubation (almost certainly due to a high rate of associated aspiration)[38]

Early studies show that field intubation is infrequently used in civilian trauma, perhaps because of its high failure rate. In a 1983 study of pre-hospital endotracheal intubation in Boston, only 16.2% of 178 field-intubated patients were trauma victims (e.g., blunt and penetrating injury, drowning and asphyxiation) [42] In a 1984 study of field intubation in Pittsburgh only 4% of attempted intubations were on trauma patients and of these almost one-third were unsuccessful.[43]

This failure rate in trauma patients was dramatically higher than the less than 10% failure rate cited in later studies.[44] Abraham et al. reported that based on unpublished data of field intubations performed on Israeli military trauma victims the failure rate of the first intubation attempt could exceed 40%.[45] Based on this preliminary finding the authors conducted a study to determine which factors might raise the risk of problematic intubation in soldiers. They concluded that difficult field intubations in soldiers is most probably unrelated to anatomical causes (e.g., high Mallampati score), and is more likely due to "complicated scenarios and deficient skills…."[44]

Thus much of the literature does not support intubation of combat casualties specifically showing that

- Pre-hospital intubation is rarely required for trauma patients (civilian or combat); the great majority of combat casualties who require intubation do so because they are to undergo general anesthesia and subsequent surgery;[14]
- There are virtually no survivors in intubated trauma patients who sustain other than head and/or facial trauma
- Blunt trauma to the head, neck, or face, which is proportionately much more common in civilian settings than in combat, is more likely than penetrating trauma to produce a patient who will benefit from advanced pre-hospital airway intervention
- A sizable portion of trauma patients with airway obstruction have a problem that is correctable with suctioning, basic airway maneuvers and/or proper positioning of the patient
- There is a high incidence of failure when intubating trauma patients, even in systems where the

overall intubation success rate is high

Finally, it is important to recognize, as Karch et al.[38] point out, that "Neither the success nor the complication rate for field intubation of trauma patients is known with any certainty."

### *Complications*

Despite numerous case reports in the literature, including reports during routine anesthesia care, pharyngoesophageal perforation is an under-appreciated complication of tracheal intubation[27] that may cause life-threatening injury. Overall mortality after esophageal perforation is high (25%), even with rapid diagnosis and treatment.[45] Difficult intubation, emergency intubation, and intubation by inexperienced personnel are risk factors for pharyngoesophageal perforation.[45]

Even if military pre-hospital medical personnel are trained in advanced airway procedures, it is likely that a substantial number of intubation attempts will be unsuccessful. Despite the fact that civilian paramedics are well trained in airway management and frequently respond to patients in respiratory distress, in some systems as many as 25% of endotracheal tubes inserted by pre-hospital personnel in urban emergency medical systems are misplaced.[46] Although a number of studies showing high intubation success rates for civilian pre-hospital personnel have been published, it is unlikely that such rates could be obtained by military pre-hospital personnel even if there were an indication for the procedure. Reasons for this are as follows:

- Paramedics in emergency medical systems that report 90+% success rates for intubation generally have relatively frequent opportunities to perform indicated intubations
- These paramedics are also, in most instances, part of an emergency medical system that has an intubation skills sustainment requirement of performance of a set number of intubations under the supervision of an anesthesiologist on an annual basis
- There is also reason to suspect, in a number of instances, that the actual intubation success rates in civilian emergency medical systems studies are not actually as high as reported (Mizelle et al. note that in many reported series, intubation success is defined by the intubator and is unconfirmed by an independent observer utilizing an objective measure such as capnographic waveform analysis[25])
- Trauma, not disease, is the predominate cause of airway difficulties in a combat setting and, as was previously noted[38], the intubation success rate in trauma victims, even by experienced paramedics, is significantly lower than the average rate.

According to a 1987 study, anesthesia residents require a mean of 58 intubations before they become successful more than 90% of the time, and require more than 90 intubations to be successful more than 95% of the time.[47] If this learning curve applies to highly trained physicians working in a generally well-controlled, well-lit, well-equipped hospital environment, how can pre-hospital personnel with less training, less experience, and operating in an uncontrolled and suboptimal environment have equal

or better success rates?[25] It is also likely that serious complications are relatively common following pre-hospital intubation, particularly when the intubator is inexperienced, as most military pre-hospital providers are; and especially when the procedure is done in a chaotic combat environment. Dr. Ron Walls, a recognized expert in difficult airway management, notes that many factors increase the difficulty of intubation, including the following, many of which are present in trauma victims in a pre-hospital setting:

- Inability to achieve the necessary alignment of the geometric axes,
- Limitations to oral cavity access,
- Interference with the passage of an endotracheal tube, and
- Distortion of normal anatomy.[48]

Further compounding these difficulties is the fact that trauma patients are often uncooperative or even combative due to pain, hypoxia, and/or brain injury. All of these factors, combined with others common in combat situations such as extreme cold or heat, poor visibility (due to darkness, sand, etc.), influx of large numbers of patients at once, incoming enemy fire, and need for rapid extraction to name a few, may make intubation difficult, if not impossible, even for individuals who are experienced in airway management.

In 2004 Wang, Davis, Wayne, and Delbridge[49] did a thorough review of the evidence supporting pre-hospital rapid sequence intubation. They came to the conclusion that,

> *A growing body of evidence suggests that invasive airway management comes with a price that may outweigh any benefits with regard to oxygenation and airway protection. Thus, it may no longer be acceptable to simply arrive at the hospital with an endotracheal tube in place; instead, the means by which the ETI [endotracheal intubation] was achieved and the adverse physiologic conditions imposed upon the patient during the procedure may be more important. In fact, these results force us to ask whether early ETI itself is beneficial at all in any patient subsets.*

### *Establishment of a Surgical Airway*

Although intubation is indicated in some cases, the majority of patients with airway obstruction resulting from combat-associated trauma can be managed successfully with simple positioning and/or suctioning; some, however, require surgical intervention. In many of those who do not respond to basic airway management techniques, endotracheal intubation is not possible for the reasons previously described.

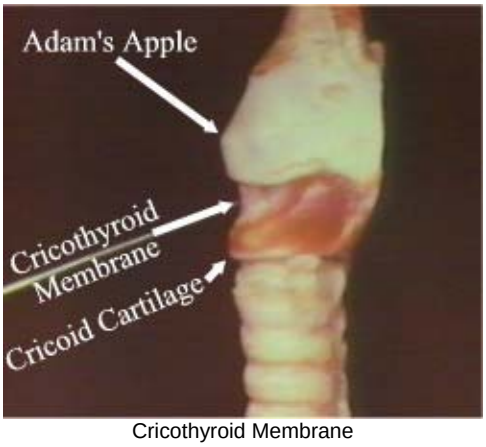
For this reason the only advanced airway technique taught by medical educators for the British Special Air Services to their highly specialized medics is a surgical airway; they do not teach endotracheal intubation. This is a logical decision given the epidemiology of combat-associated airway obstruction. It should, however, be noted that there is no evidence indicating that this approach saves more airway-obstructed casualties than intubation or even just basic airway maneuvers, or that total mortality (including those associated with inappropriately performed or unindicated surgical airway procedures) is reduced.

### *Cricothyrotomy Training*

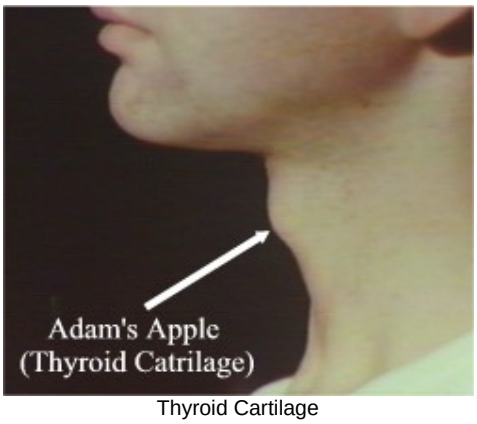
Because the "can't intubate, can't ventilate" circumstance, although quite rare, does occur, should pre-hospital personnel be taught to establish surgical airways as a last-ditch method? A recent panel discussion involving emergency medicine physicians, trauma surgeons, and combat medics conducted at the Special Operations Medical Association annual conference in Tampa Florida (December 9, 2003, moderated by this author)[50] addressed this question but did not reach a consensus.

A number of the panelists stated that all military pre-hospital personnel who are taught and authorized to perform endotracheal intubation should be taught and authorized to perform cricothyrotomies as well. There was consensus, however, that those authorized to perform cricothyrotomies must be properly trained, their competency effectively evaluated (a good simulator is needed), and their competency sustained over time.

It is important to note that both the initial and sustainment training needed to achieve and maintain competency in this procedure are relatively expensive in time, human resources, and equipment. Given the rarity of treatable life-threatening airway problems in combat casualties that require a surgical airway, it is worth asking whether these resources might be better allocated to more pervasive problems, such as ensuring highly effective hemorrhage control.



Cricothyroid Membrane



Thyroid Cartilage

Training to establish a surgical airway is problematic because it is very difficult to replicate the circumstances, anatomy, and pathophysiology of a combat casualty with a traumatically obstructed airway. In reality, patients with complete, or near-complete, obstruction of the airway are either struggling for air (not lying still) or they are very near death from hypoxia (extreme urgency); both of these situations can make the procedure difficult even for experienced physicians. In a combat setting, many patients with airway obstruction will have penetrating trauma of the neck and/or face with hemorrhage that extends into the anterior neck, distorting the anatomy (often the source of obstruction) and presenting a risk of exsanguination if a

surgical airway is attempted. Proper lighting, asepsis, and other environmental considerations are also frequently far less than ideal in a combat setting.

Current surgical airway management training is limited by the use of plastic models and cadavers which do not bleed or struggle and die. New sophisticated simulators can replicate physiology [http://www.meti.com] and thus are a significant improvement over simple plastic models and some of the new plastics are very lifelike and can even simulate bleeding when cut. Animal models such as large goats and pigs are much better for training purposes but they are expensive and the use of animals is becoming increasingly problematic. Interestingly, it is documented that as long ago as 1000 AD, Ibn Zuhr is reported to have successfully performed a tracheotomy on a goat, so this animal model for a surgical airway has a long history [http://www.entlink.net/museum/exhibits/Early-History.cfm?renderforprint=1].

Large pigs are the best animal model for surgical airway training because, of the animals used for this type of training, their anatomy is the closest to that of humans. Goats, by comparison, have a very long and superficial trachea that is easily accessible with low risk of serious hemorrhage. For this reason, it is deceptively easy to perform cricothyrotomy on a goat; successful students gain a false perception that the procedure is easy to perform in a combat casualty. The other problem with animal models is that the animals are anesthetized when the airway procedure is performed (not struggling), their anatomy is not distorted, and they generally have no airway obstruction so there is no risk of immediate death. Army combat medics in the 91W training program currently (as of 22 June 2004) receive two hours of lecture/discussion and twelve and one-half hours of practical exercise on all aspects of airway management; 30 minutes of this being dedicated to didactic teaching of a surgical airway and 4 hours spent on a practical exercise teaching a standard cricothyroidotomy. Previously this instruction had included training on the use of the Cook Melker percutaneous cricothyrotomy device[51] but, because of the lack of a inexpensive training device for the Melker airway this was discontinued.


Top: Rick Rescorla, left, and Myron Diduryk. Clinton Poley, center, in the battalion aid station. Bottom: Doc Carrara works on Arthur Viera.

Arthur Viera receiving a surgical airway by Doc Carrara at LZ X-Ray in Vietnam, in ***We Were Soldiers Once - And Young***, by Joe Galloway and Hal Moore. Viera is obviously awake, alert, and has survived for some period of time with his penetrating neck wound.

Combat medics (91W) are now taught to perform a standard emergency crichothyroidotomy with insertion of a small endotracheal tube. [91W Lesson Plan Airway Management C191W002 / Version 1 22 June 2004 - 300-91W10 1 Health Care Specialist Task 081-833-4528 Perform a cricothyroidotomy]

Sustainment skill training in cricothyrotomy skill training is a unit responsibility and units, for the most part, do not have models or devices for providing this training. The reality is as follows for most medics who would perform a surgical airway procedure on a combat casualty:

- He or she will have never before done the procedure on live tissue (animal or human)
- The last time he or she did the procedure was on a plastic manikin, more than a year before, during a mandated (not unit) training requirement
- The procedure will be unsupervised by someone experienced in the successful performance of the procedure
- The surgical environment will be far from ideal.

All of these factors suggest that when a combat medic performs a cricothyoidotomy on a casualty with an apparent airway obstruction there is a reasonably high probability that the procedure will be done when not indicated and/or it will be unsuccessful. In fact the procedure is most likely to be successfully performed on casualties in whom it is not indicated because they are less likely to have grossly distorted anatomy, they are probably not struggling, and there is likely less urgency, so the procedure can be performed in a more controlled manner. While it is certainly true that there are some situations in which a surgical airway would be indicated in a patient without an immediately critical airway obstruction, the ability of a combat medic to discern this patient from one who does not need this procedure is probably not very good.

### *Risks*

Unfortunately, it is quite possible that although some patients could be saved by establishment of a surgical airway, almost as many may be killed or permanently harmed by the procedure itself. Inexperienced medics in the field are not only less likely to effectively manage an airway using non-surgical methods but they have a higher likelihood of complications and a lower likelihood of success when attempting to open an airway surgically. If the adverse outcomes only occurred in patients who truly had airway obstruction that couldn't be relieved with less-invasive methods, there would be no harm in attempting to establish a surgical airway (no matter how unskilled the medic) because otherwise these patients would surely die. Unfortunately, the less trained and less experienced the provider, the more likely it is that a surgical airway will be attempted when it is not indicated; which subjects patients who do not stand to benefit from the procedure to increased risk of complications and death.

It is worth noting that the recipient of the first recorded "successful" cricothyrotomy, performed in 1852, later died from airway stenosis.[52] Cricothyrotomy is associated with a historically high rate of difficult-to-manage subglottic stenosis and other complications that include life-threatening hemorrhage, airway obstruction, bronchospasm, cuff leak, esophageal perforation, paratracheal insertion, aspiration, infection, pneumomediastinum, pneumothorax, subcutaneous emphysema, or tracheoinnominate fistula.[53] Given the rarity of combat trauma patients sustaining airway obstruction that requires surgical intervention, it is

probable that the number of times this procedure would be done when not indicated is likely to greatly exceed the number of times it would be done when indicated; and some percentage of these casualties will suffer procedure-associated complications.

Although similar concerns exist about the establishment of a surgical airway when performed by a physician's assistant or medical officer, these individuals should have had more training and more experience than the typical combat medic. The Israeli experience, as reported in a 1997 study of physician-performed pre-hospital cricothyrotomies, is that cricothyrotomy performed in the field by physicians, even ones inexperienced in the performance of cricothyrotomy is successful in most (89.6%) cases.[54] In this study cricothyrotomies were done on only 3.3% of all patients requiring pre-hospital airway procedures; nearly two-thirds having sustained penetrating trauma (Israel may be somewhat unique among developed countries because of its disproportionately high percentage of patients sustaining penetrating trauma). It is, however, unclear how these cricothyrotomies were deemed successful or unsuccessful. Because there is no indication in this study that autopsies were performed on those who died, it is not possible to determine whether the cricothyrotomy was an associated cause of death or even whether the procedure had been performed properly

Statistical analysis notwithstanding, the reported success rate in the above study may well be inflated because:

- Overall mortality was 55.1%
- Lack of autopsy confirmation of airway success or failure among the dead makes it unclear how many attempted cricothyrotomies were successful [Note: the authors do suggest that the procedure was not the cause of death stating "Since the RTS and GCS were significantly higher among the survivors, it appears that the high mortality rate in this series was injury-related" and was not related to the procedure.[54]]
- Success was not defined using any objective measure such as confirmation of end-tidal CO2. (i.e., it was determined subjectively by the performer of the procedure, was not independently verified, and was defined as the establishment of an effective airway and achievement of "reasonable" ventilation as determined by auscultation).

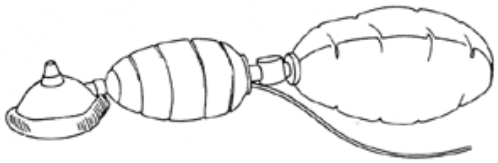
There is also reason to believe that some of the patients reported in this series did not actually need a surgical airway. Three patients, despite having an unsuccessful cricothyrotomy and experiencing associated complications, arrived at the hospital alive, surviving both their "airway obstruction" and their unsuccessful surgical airway attempt. These issues aside, the authors note that following brief training (e.g., the ATLS course) physicians are apparently capable of performing emergency cricothyrotomies in the field and their success rate without complications appears to be unrelated to medical specialty.

Certainly in the context of the failed airway, cricothyrotomy provides the ultimate fallback airway management technique and, as such, it should be in the armamentarium of the forward-deployed physician's assistant and medical officer.[48]

### *Equipment - Non-surgical Airway Management*
### *Bag-Valve Mask*

Although a bag-valve mask is an essential item of equipment for assisted ventilations, it is reasonable to question its utility forward of a Battalion Aid Station. In a civilian setting respiratory arrest in patients with non-traumatic injury is not uncommon and many such patients can be saved with ventilatory assistance. Further, respiratory arrest in civilian trauma patients is generally due to closed head injury; some of which can be saved with ventilatory assistance. In combat, however, trauma-associated respiratory arrest is usually due to penetrating trauma, and very few patients with such injuries can be saved even with good ventilatory assistance. As is true with advanced airway procedures there are certainly some combat-associated circumstances for which ventilatory assistance may be life-saving in the forward combat areas; these include, but are not limited to:

- Closed head injury
- Electrical shock
- Lightning injury
- Chemical warfare (particularly those involving the use of nerve agents)
- Drowning.



Bag-Valve Mask, from from United States Naval Hospital Corpsman 3 & 2 Training Manual NAVEDTRA 10669-C June 1989

Not only is the bag-valve mask unlikely to favorably improve the outcome of most combat casualties, but most providers find it difficult to use this device effectively as a sole provider. The American Heart Association in their Advanced Cardiac Life Support Course clearly state that, "a single rescuer may have difficulty providing a leakproof seal to the face while squeezing the bag adequately and maintaining an open airway." For this reason, manually operated, self-inflating bag-valve-mask units are used most effectively by at least two well-trained and experienced rescuers working together."[55] A smaller and lighter item, which is can be much more effectively used by a single person, is the pocket mask. For the majority of far-forward, point-of-wounding, circumstances the pocket mask is not only sufficient but is a superior choice.

### *Suction Devices*

As indicated earlier, vomitus, blood, and tissue are common causes of airway obstruction in combat casualties. Most, but not all, of these common causes of obstruction can be cleared by proper casualty positioning and digital clearing of the airway. Various suctioning devices are available to aid in the clearing of liquids and small particulate matter from the airway. The ideal battlefield suction device should be:

- Lightweight
- Compact
- Durable
- Effective
- Hand operated.

Many of the suction devices used by civilian EMS personnel are electrically operated. In addition to requiring electrical power such devices are generally

too bulky and too heavy for use by combat medics who must rely on hand-operated devices.

V-VAC™ Manual Suction Unit (Photo courtesy of Laerdal Medical Corporation)

In a recent evaluation of several commonly used, commercially available, hand-operated suction devices (along with some prototype devices and a 60-mL Toomey syringe) by 17 Special Operations Forces enlisted medical personnel, the modified Delee suction device and the V-VAC™ Manual Suction Unit (whose major drawback was its bulky, non-compressible, size ) were preferred.[56]

As a field-expedient, small, simple, readily-available suction device, the 60-mL Toomey syringe, although less than ideal because it does not come with an aspirator tip, it has a narrow opening and thus is not effective at removing most thicker and particulate matter, and because it has a limited capacity, seems to be the best of the options currently available because of its ease of use and ready availability.

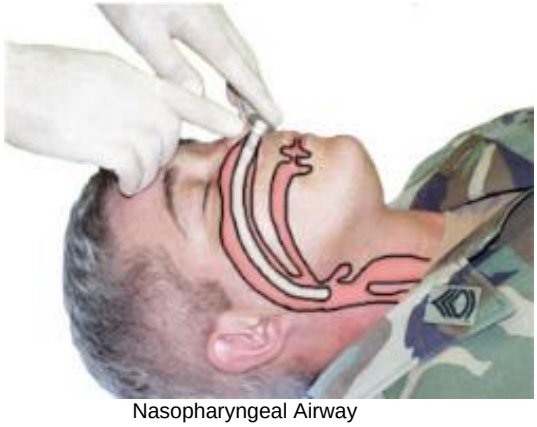
An aspirator, called the SuctionEasy™ disposable suction is now available that meets several of the characteristics of an ideal combat suction device. It is essentially a modified and enlarged infant bulb aspirator with a reservoir that can hold up to 1000 cc's of aspirated material.

It is simple to use, has no moving parts, is lightweight and reasonably compact, has an aspirator tip as large as that on most commercially available suction devices for pre-hospital use, and is capable of generating a vacuum force of approximately 100 mm Hg – more than sufficient suction to clear blood and vomit from an adult airway. This suction device might also be used in lieu of an esophageal detector device to confirm endotracheal tube placement (see following discussion below) but it has not been evaluated for this application nor has it been tested against other suction devices to determine its efficacy in the hands of military pre-hospital personnel.

### *Airway Adjunct*

Almost by definition, any patient who can tolerate proper placement of an oropharyngeal airway needs to be intubated, and probably needs at least some assisted ventilation. In conventional combat the majority of casualties in whom an oropharyngeal airway would be indicated have severe neurological injuries or are in severe shock. Survival of such patients, even when properly managed and under relatively ideal circumstances, is unlikely.


Oropharyngeal Airway


Nasopharyngeal Airway

For these reasons, in combat, oropharyngeal airways, even if properly used, are unlikely to have much effect on morbidity or mortality. An alternative airway adjunct is the nasopharyngeal airway. This airway can be used in both responsive and unresponsive patients and, if used properly, can be safely inserted in most patients with facial trauma.

### *Airway Device*

There are currently available a number of airway devices that do not require direct visualization of the vocal cords and are designed to be inserted blindly.[57] Earlier devices such as the esophageal obturator and esophageal gastric tube airways were single-lumen airways designed to obstruct the esophagus and direct airflow into the trachea. These devices were associated with an increased risk of death, frequently because of unrecognized tracheal instead of esophageal obstruction; they have been described a prominent trauma surgeon, Ken Mattox, as being "instruments of the devil."

Some of the newer devices are double-lumen devices that can be inserted either into the trachea or the esophagus and, if the proper ventilation tube is selected, allow for effective assisted ventilation with a bag-valve mask. The Combitube™ [http://www.life-assist.com/combitube], pharyngotracheal lumen airway [http://www.gettig.com/ptl], and the laryngeal tube airway are examples of devices that have a large-volume balloon that inflates in and seals the posterior pharynx and a distal balloon of smaller volume that inflates in the trachea or, more often, in the esophagus.[58-60]

With these devices it is critical to correctly identify which port to ventilate.[61] After confirming the location (trachea or esophagus) of the distal tip of the airway, which is best accomplished using an end-tidal CO2 detector, ventilation is provided through the proper port. In addition to helping secure a patent airway, the upper, large-volume balloon on these devices can potentially compress and control bleeding in the upper airway and thus, in some instances these devices may be the ideal airway device for some patients with maxillofacial trauma. The pharyngotracheal lumen airway was evaluated for its ability to control simu-

lated upper airway hemorrhage and was found to be effective.[62]

Another type of blind insertion device is the laryngeal mask airway. When inserted this device creates a seal around the upper portion of the airway in the posterior pharynx thus directing air into the trachea. All of these devices have been tested both by anesthesiologists in an operating room setting and by prehospital personnel in a field setting and have been found to provide effective ventilation comparable to endotracheal intubation if used properly.[63] In a study of endotracheal tube, laryngeal mask airway, and Combitube™ use by Navy Seal and Reconnaissance combat corpsmen under simulated combat conditions, insertion time for the laryngeal mask airway (22.3 seconds) was significantly shorter than the insertion times for the other devices.[64] The corpsmen easily learned how to use the Combitube™ and laryngeal mask airway, and had a similar rate of attempts for all devices (1.17 to 1.25). The authors concluded the following:

> *Simple airway devices that allow for easy learning, rapid insertion, and minimal deterioration in skill over time could significantly improve corpsmen's' ability to care for patients in combat conditions*.

It should be noted that complete airway protection is only provided in those instances in which a cuffed airway is placed in the trachea. Some of these blind insertion devices can easily be converted by a physician to a cuffed endotracheal tube in a controlled environment. Although generally safe and easy to use, these devices are associated with occasional complications. In 91W training it is the Combitube™ that is taught for advanced airway management.[65]

### *Devices to Confirm Endotracheal Intubation*

Although endotracheal intubation is not generally indicated for most combat trauma patients (see above discussion), if it is performed, it is absolutely essential that confirmation be obtained that the trachea, and not the esophagus, has been intubated. The former gold standard of observing the tube pass through the vocal cords, confirmation of bilateral breath sounds on ventilation, and absence of ventilation sounds over the stomach is inadequate.[66] The new prehospital gold standard is capnographic confirmation of the excretion of carbon dioxide, usually with a colorimetric CO2 detector. Another commonly available, field-durable, and effective confirmation tool is the esophageal detector device, or EDD. This is a bulb-suction device that relies upon the fact that when suction is applied to the end of the endotracheal tube, the esophagus, but not the trachea, will collapse. Confirmation of tracheal intubation is obtained when the EDD is placed on the end of the ET tube, compressed, and rapidly refills when compression is released. Either, or preferably both, of these confirmation tools should be used any time endotracheal intubation is performed.[66-71]

No single method is completely adequate to confirm proper tube placement with 100% certainty so whenever possible multiple methods should be used together to achieve the highest degree of certainty possible. Unfortunately unrecognized esophageal intubation continues to be an all-too-common cause of iatro-

genic mortality in the pre-hospital setting.

### *Equipment for Surgical Airway Management*

It is not the intent here to describe, in detail, how to perform a surgical cricothyrotomy or to list each item needed to establish a surgical airway; this information can be found in many other places.[72] The intent is to highlight critical steps, compare different methods and equipment, and assess the efficacy of these different techniques when applied by pre-hospital personnel.

### *Standard Surgical Airway Equipment*

The basic equipment required to establish a surgical airway using the standard technique is limited and, largely for this reason, the standard technique is often preferred. Several of the required items, such as a scalpel with a # 11 blade, gauze, hemostats, needle holder, and scissors are commonly found in medic/corpsmen aid bags.

Other helpful items that are not generally carried include a tracheal dilator, a tracheal hook, and a low-pressure cuffed tracheotomy tube such as Protex or Shiley (size 5 or 6, with an 8-mm or larger internal diameter).

Although a surgical airway can be established with just a knife and an appropriately sized, cut-down, endotracheal tube (or less[73]), this procedure, which might seem easy when performed on an anesthetized goat, can go disastrously wrong when performed with improvised, inadequate, equipment under suboptimal conditions. Proper performance of this procedure is outlined well elsewhere.[72]

Establishing a surgical airway using standard surgical technique and minimal equipment can certainly be done by a trained combat medic. Unfortunately, the circumstance in which this standard surgical approach is easiest to perform in a combat setting is when the casualty is not struggling and when there is minimal to no bleeding -- conditions most commonly found in casualties who are already dead.

### *Cricothyrotomy. Percutaneous Dilational Cricothyrotomy*

Although the Israelis[53] and others[74] have found similar complication and success rates between the standard surgical airway approach and the Seldinger technique (and found that the standard approach was faster) others have suggested that a Seldinger or modified Seldinger technique is faster, has lower complication rates and higher success rates.[75, 76] A major problem with some of these comparative studies is that the two different cricothyrotomy techniques have been evaluated using cadavers, which don't bleed, move, or have distorted airway anatomy.[72, 75]

Toye & Weinstein[76] introduced the technique of percutaneous tracheostomy in 1969. The technique was subsequently modified by Ciaglia et al.[77] in 1985 and has gained widespread acceptance among surgeons and intensivists. The advantages of this technique include a small skin incision, less soft-tissue dissection, and wire-guided, controlled placement of the airway into the trachea. Advocates of percutaneous tracheostomy cite the ease and ability with which non-surgical specialists can per-

form this technique outside the operating room.[78]

A number of percutaneous cricothyrotomy kits are marketed (such as the Pertrach™, Nu-Trach™, Melker Emergency Cricothyrotomy Catheter Set, and the Rapitrach™, to name a few). Each of these devices utilize a similar concept, that is the insertion of a needle into the trachea, through which a guidewire is inserted (Seldinger technique) followed by dilation of the puncture site with a wire-guided dilator to facilitate placement of a functional airway.

The Pertrach™ device combines the guidewire and the dilator and uses a unique, splittable needle that is divided and removed once the combined guidewire/dilator has been introduced – this simplifies the insertion process and reduces insertion time. Both an advantage and a disadvantage of the Pertrach™ device is that it uses a cuffed airway. While a cuffed airway is ideal and reduces the risk of aspiration the cuff increases the diameter of the tube that must be inserted and thus makes insertion more difficult – significant insertion force is often required with this device.

Advantages of all of these Seldinger-type devices over standard surgical dissection include less bleeding, ease of learning, and more rapid insertion. A study by Toye & Weinstein in 1986 of 100 patients treated with an early version of the Pertrach™ device revealed a total complication rate of 14%, of which 6% was due to false passage of the device, or paratracheally rather than intratracheally.[79]

An unpublished in vivo evaluation of four cricothyroidotomy devices carried out at the Institute of Surgical Research, Brooke Army Medical Center, Fort Sam Houston found that of the devices available in 1990 (the Melker device was not available at that time), the Pertrach™ was the most rapidly inserted by non-surgically-trained practitioners into a porcine model.[80] Because each of the available Seldinger-type surgical airway devices includes some type of dilator to create an opening in the cricothyroid membrane, tissue dissection is minimized.

When a cuffed airway is to be inserted, the opening through the skin and into the trachea has to be larger than the dilator. Unless an incision is made that is large enough to facilitate easy passage of the cuffed airway, significant pressure will be required to insert the cuffed airway.[81]

Use of lubrication on the airway can help to reduce insertion forces. Special Operations medics in training at the Joint Special Operations Medical Training Center in Fort Bragg, North Carolina informally assessed the Pertrach™ and Melker devices in terms of ease of use. Their primary complaint about the Pertrach™ was that significant force was required to insert the cuffed airway. They tended to prefer the Melker device because it was easier to insert. The Melker device has a significantly smaller internal diameter than the Pertrach™ and does not have a cuff.

Although a smaller uncuffed airway may be an adequate rescue airway device it is inadequate for sustained use (beyond more than a few hours) because of the increased work of breathing and because the lack of a cuff increases the risk of aspiration. When a casualty arrives at a medical treatment facility with

a small, uncuffed, airway, the airway will have to be replaced. Although this is a disadvantage, an uncuffed airway can certainly be replaced later with a cuffed airway in the more controlled setting of the medical treatment facility. For this reason it might not be unreasonable to select from among the available surgical airway devices and techniques the one that is fastest, easiest, and least risky for pre-hospital personnel to employ, even if it must later be replaced.

Previously the Army Medical Center and School at Fort Sam Houston had taught 91W combat medics to perform percutaneous cricothyrotomy using the Melker device but this has been discontinued because the lack of a cost-effective training device limited effective training. Currently combat medics are taught to perform a standard surgical cricothryoidotomy with the insertion of a small endotracheal tube.

### *Evacuation of Casualties with Maxillofacial Injuries*

In World War II it was found that with proper forward area medical care casualties with maxillo-facial wounds could receive delayed definitive medical care without adverse consequence. The history of the activities of the 2nd Surgical Group states that, "In the average maxillo-facial case immediate surgery is not imperative and in the presence of haemostasis, clear airway, and a reasonably comfortable patient, it is wise first to reduce shock to a minimum."[3] This history also reveals that "The mean average time from [facial soft tissue] injury to first definitive treatment was eight hours" and, "The mean average time from injury to arrival at the Center [2nd Auxiliary Surgical Group] was four days." It was noted that, "Many cases will require time-consuming operative procedures…therefore surgery should be attempted only under controlled conditions."[3]

During World War II it was determined, based on experience, that casualties with serious maxillofacial injuries were best handled in evacuation hospitals, where trained oral and maxillofacial surgeons could be readily available to treat them. It was felt that maxillofacial teams were more usefully employed in the rear areas at evacuation hospitals rather than in field hospitals. It was found that if hemorrhage could be controlled and a proper airway established and maintained that casualties with maxillofacial trauma could tolerate transportation very well if kept in a prone (not supine), or sitting up and leaning forward, position. It was, however, noted that such casualties may require the attention of special attendants during evacuation.[82]

## *SUMMARY*

Although having a patent airway is critical to survival, advanced airway management of combat casualties by medical specialists is rarely required. Penetrating trauma, the predominant form of trauma on the battlefield, infrequently produces airway obstruction and when it does, the obstruction is usually immediate, causing death before treatment by a medical specialist is available. Further, the majority of treatable airway obstruction that occurs in combat casualties can be managed by basic airway maneuvers that include proper positioning, suctioning, digital removal of debris from the airway, head tilt/jaw thrust, and insertion of a nasopharyngeal airway.

Advanced airway management, specifically intubation and cricothyrotomy, is very rarely required for combat casualties. At, or near, the point of wounding there is a high probability that these rarely performed procedures will be done incorrectly, when not indicated, or both – especially when performed by personnel with minimal training and inexperience with the techniques. All of this leads to a reasonable conclusion that the emphasis of airway management training for soldiers and medics needs to be on well-executed basic airway clearing maneuvers using either no airway adjuncts or simple, durable, lightweight, and uncomplicated equipment; perhaps the most important of these being effective suction. In addition to hemorrhage control, all soldiers should be taught proper casualty positioning and basic airway clearing techniques. Realistic simulators capable of recreating the types of airway obstruction likely to be found in battlefield casualties and able to be utilized in realistic combat scenarios are essential for effectively training pre-hospital personnel. Training therefore, and not equipment, should be the primary focus of efforts to improve the survival of combat casualties with airway obstruction. If military pre-hospital personnel are to be taught to perform advanced airway procedures such as endotracheal intubation, rapid sequence intubation, and/or cricothyrotomy, it is essential that they be properly trained, sustained, and evaluated to ensure competency. They must also be equipped with, and trained in the use of, airway rescue devices that are easy and safe to use and there must be some mechanism of oversight put into place to ensure that these procedures are being done properly and only when indicated. Further, it is important to conduct studies to determine whether overall survival of combat casualties is actually increased through the use of these procedures by pre-hospital personnel.

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