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CRITICAL CARE

REVIEW

Prehospital endotracheal intubation: elemental or detrimental?

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Abstract

This article is one of ten reviews selected from the Annual Update in Intensive Care and Emergency Medicine 2015 and co-published as a series in Critical Care. Other articles in the series can be found online at http://ccforum.com/series/annualupdate2015. Further information about the Annual Update in Intensive Care and Emergency Medicine is available from http://www.springer.com/series/8901.

Introduction

Modern out-of-hospital emergency medical services (EMS) systems, as we have come to recognize them today, were established in the 1960s and 1970s when a cadre of intrepid physicians ventured into the streets and later published their successful experiences with lifesaving approaches to managing acute coronary syndromes, trauma care, and cardiopulmonary arrest on-scene [1-3].

Although physician-staffed ambulance services had been in place in many venues worldwide for more than a century, the late 20th century evolution of prehospital care was highlighted by documentation of life-saving outcomes in those first modern EMS programs and their use of invasive 'advanced life support' (ALS) procedures including prehospital endotracheal intubation (ETI) and intravascular (i.v.) cannulation for drug administration [1-3]. These life-saving reports helped to propel the widespread adoption of EMS systems and the concomitant introduction of specially-trained (non-physician) emergency medical technicians called 'paramedics' [1-5]. Eventually nursing personnel also ventured into the realm of on-scene emergency response, particularly in the arena of air medical services.

This evolution in out-of-hospital care was especially remarkable in that the formal training of these non-physician personnel included those advanced care interventions such as ETI and i.v. drug administration, interventions traditionally provided in the in-hospital setting by expert physician specialists [1-9]. Paramedic skill portfolios ranged from basic spinal immobilization and extremity splinting to the more advanced skills of electrocardiographic (EKG) interpretation, defibrillation attempts, ETI, i.v. catheter placement and even pericardiocentesis and tracheotomies in some communities [10].

The skill of ETI had become the definitive airway control for most critically ill and injured patients, be they in the operating room, in the early phases of an intensive care unit (ICU) hospitalization, or in the out-of-hospital setting [2-9,11]. The presumed presence of significant physiological derangements (e.g., hypoxemia, hypercarbia, hypoperfusion) in cardiopulmonary arrest, head injury and hemorrhagic states made ETI an intuitive procedure to perform as soon as feasible in the critically ill and injured [4,5,9,11].

In addition, there were other clinical care imperatives (e.g., airway protection, ventilatory control, end-tidal carbon monoxide monitoring, drug administration and airway suctioning) that drove a strong philosophy that EMS personnel should provide a definitive airway as soon as possible in the out-of-hospital setting for cardiopulmonary arrest, severe trauma and other life-threatening emergencies [2-9,11]. Nevertheless, although these invasive skills were now being provided by paramedics and nurses, for the most part they were still being delegated under the direction of accountable physician supervisor experts in out-of-hospital care [12]. Early studies conducted in EMS systems with intensive, expert physician supervision, comprehensive training programs and on-scene supervision of EMS personnel reported extremely high rates of successful ETI for both children and adults [2-8,13-15].

In most of these studies, success was defined not only by accurate anatomic placement of the endotracheal tube

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(ETT), but also by absence of significant complications [3-7]. Moreover, prehospital ETI was soon correlated with positive outcomes particularly in the most dire of circumstances [7,8,15].

For the most part, prehospital ETI has usually been performed in cardiopulmonary arrest cases and in the most severely injured trauma patients with significant physiological impairment (unconscious) and, generally, no gag reflex [5]. As a result, the procedure can be relatively easy to perform by highly-experienced care providers. However, using unqualified univariate analysis, ETI is typically performed in those patients with a high-risk of associated morbidity and mortality and thus can be simplistically *correlated* with a poor outcome [16-20]. Paradoxically, in some selected EMS systems, ETI has actually been correlated positively with survival, particularly in cases of post-traumatic circulatory arrest [7,8]. In turn, this paradoxical finding infers a likely value of ETI in these worst-case scenarios [7,8,21].

However, despite intuitive biases and impressive inferential studies indicating the positive effects of prehospital ETI in certain settings, another evolving body of studies and experiences has unveiled a detrimental effect of prehospital ETI or, at least, no significant advantage to providing the procedure [17,20,22-29]. Most notably, a controlled clinical trial conducted in the 1990s in a pediatric population generated significant concern about prehospital ETI in that vulnerable population and subsequent studies in adult head injury patients amplified that concern [25,26]. In the pediatric ETI trial, 830 children (age 12 years or younger) were studied over a three-year period [26]. Although not statistically significant, survivors with positive neurological outcomes were slightly more frequent (92 of 104; 23%) in those managed with bag-valve-mask (BVM) devices (23%), versus 85 of 416 (20%) receiving ETI [26]. In a subsequent case–control study of severely head-injured patients receiving ETI that was facilitated by rapid sequence induction (RSI), outcomes were worse for patients receiving the procedure versus those with similar injuries not receiving it [25]. Also, in deference to other studies indicating a survival advantage to ETI in post-traumatic circulatory arrest [7,8], the on-going univariate association of ETI with mortality in recent studies, though predictable, has fueled the debate that ETI should no longer be used in the out-of-hospital setting [16-18,23].

Adding to this debate has been the concern over interruptions in well-performed chest compressions during cardiopulmonary resuscitation (CPR), the key factor in restoring return of spontaneous circulation and eventual survival following cardiac resuscitation. It is argued that pausing to intubate could, therefore, be detrimental under these circumstances [30,31]. In turn, ETI has lost priority standing in many venues.

Along with its lowered prioritization in cardiac arrest management, it has been argued that, overall, there is no strong evidenced-based support for ETI in terms of survival advantage. So despite the logical value of performing it in critically ill and injured patients, many have argued that a true value cannot be demonstrated, particularly in children [20,23,26,31].

Regardless of this evolving sentiment to avoid prehospital ETI altogether and even consider it as a deleterious procedure, that 'evidence-based' position may indeed be overly simplistic. In the ensuing discussion, it will be delineated how several under-recognized confounding variables have a major impact on the performance of this skill and even related outcomes. These variables include non-intuitive factors, such as how the EMS providers are deployed or how they have been trained to ventilate [32-44]. These concepts and how they relate to the success of prehospital ETI for the critically ill and injured will be addressed in the rest of this article. It is hoped that by being provided these perspectives, one can better delineate the circumstances in which ETI should be utilized and those in which it should truly be discouraged.

Factors that affect successful prehospital ETI

Unique training challenges

As previously stated, the original EMS programs that first published success with paramedic-staffed responses generally reported extremely high rates of success with prehospital ETI placement [2-10,15]. Also, as stated, others have not demonstrated similar successes [17,20,25,26,28]. In retrospect, when examining the differences in systems that have or have not had successes in ETI, it appears that several factors are actually strong determinants of paramedic and nursing proficiency in the skill of ETI. These determinants include: 1) the quality, orientation and types of experiences in the initial training; 2) the frequency of performance; and 3) on-scene oversight and supervision of ETI performance [3-6,12,13,29,32-36].

Proper training for the prehospital environment clearly needs to be somewhat unique. In contrast to the typical operating room training experience, the skill of ETI performed in the emergency care setting, and particularly in the out-of-hospital environment, is wrought with unique challenges [5]. These challenges range from vomit-flooded airways and ground-level patient positions to ambient lighting and oro-pharyngeal injuries. With full stomachs, relaxed esophageal sphincters and inadvertent gastric insufflation from BVM or mouth-to-mouth ventilation, it is commonplace to approach an airway welled-up with vomit in a circumstance with often less-than-adequate (or delayed) suctioning. In turn, this often requires the ability to intubate almost instantly without adjuncts.

Unlike the controlled in-hospital environment, in a sunny, bright outdoors setting, the ambient light causes glare and pupillary constriction for the rescuers. This circumstance requires that the practitioners are taught and understand the 'tricks of the trade', such as placing a coat or blanket over one's head (and the head of the patient) in order to create a makeshift darkened room akin to an old-time photographer's camera hood. In contrast, even in the dark of night, heavy rain or awkward confined spaces may pose their own barriers to easily visualizing vocal cords. Therefore, many of the classical techniques used by other practitioners in more traditional settings would not be as effective in the fast-paced, poorly controlled and mobile prehospital settings where resources and support are limited (Figure 1).

In turn, a key to successful EMS intubation in the out-of-hospital setting is the street-wise experience of expert highly-experienced medical trainers and EMS medical directors who not only understand these principles, but also are themselves facile in such techniques in the out-of-hospital setting [5,6,12].

Frequent skill usage and system staffing configurations

Even if initial training techniques are expert and well-taught, both in the classroom and on-scene, frequency of performance is a critical factor. For example, studies have shown the success rates for ETI can be related to the deployment strategy of the EMS system [2,3,32,33]. In EMS systems using tiered ambulance deployments in which paramedics (ALS providers) are spared for the most critical calls, many fewer paramedics are needed on the roster and the individual experience of each paramedic, including frequency of ETI performance, can be enhanced dramatically [2,32]. Accordingly, this approach has been correlated with improved success rates in terms of ETI performance [2,32].

Figure 1 Endotracheal intubation in the out-of-hospital setting. In the early years of out-of-hospital emergency medical services (EMS) systems, advanced life support personnel were not only trained in the nuances of how to avoid overzealous ventilation and properly place an endotracheal tube in very challenging circumstances, but they were also well-supervised on-scene by expert physicians who themselves were highly-experienced and exceptionally familiar with those challenges as well as methods to overcome them (photo by Dr. Paul Pepe).

This need to enable frequent experience is critical in EMS. While ETI skills may deteriorate a little with a hiatus from practice, collective experience [2,32] has demonstrated that most prehospital personnel who have performed ETI a hundred times or more in the out-of-hospital setting may still be able to perform the technique quite well despite the hiatus. However, the key issue is getting to that threshold of experience and this prerequisite goal requires high exposure and frequent performance. Unfortunately, that level of performance is not always achieved in most EMS systems today. As an example, for a five-year 'veteran' paramedic to have achieved a successful ETI over 100 times, it would mean successful performance of that procedure at least 20 times a year for five years. Most paramedic units are usually staffed by two paramedics, so if ETI experience were to be shared with a paramedic partner, the implication is that this particular team would need to face 40 ETI situations a year on their particular ambulance and shift. In fact, accounting for sick time, vacation time and other factors, it typically takes 5 to 6 fulltime equivalent paramedics to staff one of those two positions and thus 10–12 different paramedics will be needed just for that one ambulance around the clock. Therefore, that particular response unit would need to face approximately 200 to 250 ETI cases a year for each ALS provider to get 20 opportunities to intubate.

Considering that cardiac arrest, respiratory distress and major trauma cases requiring ETI constitute only 2–3% of all EMS on-scene emergency responses [32], the ambulance in question would need to experience nearly 10,000 EMS incidents a year overall. In most EMS system configurations, this level of volume would be a logistical-temporal impossibility for a single ambulance. Unless alternate deployment strategies were to be utilized, frequent exposure to ETI cases would be clearly limited.

Indeed, alternative deployments are key. Specifically, in some communities, paramedics (or other types of ALS personnel, such as doctors or nurses) are spared from the majority of EMS responses. Instead of ALS providers, basic emergency medical technicians (EMTs) trained to do the non-invasive procedures such as spinal immobilization and splinting are used for most of the responses [2,3,32,33]. Under such circumstances, overall staffing could, therefore, involve a much smaller cadre of paramedics. This would permit more frequent exposure to critical illness and injury for the individual paramedics (ALS providers). The same concept would apply to nurses or apprentice physicians who staff ambulances and air medical units, particularly in some European countries [2,32,33]. The fact that air medical units are typically triaged only to the most critical cases means that those ALS providers staffing the helicopters are part of a deployment strategy that enhances skill use. Using this so-called ‘tiered’ approach, individual paramedics (ALS personnel), nurses or doctors each get more chances to perform an ETI.

While there is great variation from one city to another, on average a city with a population of 1 million in the U.S. (for example) might be expected to have 100,000 EMS response incidents annually [45]. This volume of cases might predict two or three thousand potential circumstances for ETI each year. To optimize individual paramedic exposure, it would be best to limit the number of paramedic (ALS) ambulances to a maximum of 10 ambulances (250 ETI exposures per ambulance per year × 10 ambulances covers 2 to 3 thousand cases). In this circumstance, a cadre of 100 to 120 paramedics might be required for the 10 paramedic-staffed units.

In a contrast, in a system experiencing 100,000 EMS responses a year and using all-paramedic staffing, 35 to 40 ambulances would typically be required minimally and thus 400 to 500 paramedics would be needed [32,33]. This all-ALS provider approach decreases individual exposure to ETI attempts at least 4 to 5-fold. To make matters worse, in some cities, additional paramedics are also placed on first-responder vehicles such as responding fire engines [26,28]. In turn, this further compounds the infrequency of exposure for individuals. Moreover, some ambulances are situated in lower call volume areas than others, creating even less exposure to ETI opportunities [36].

Fortunately, the great majority (85 to 95%) of EMS incidents do not require an ALS provider (e. g., authorized physician, nurse, paramedic) and can be managed by basic EMTs [32]. In turn, using well-established and well-documented dispatch triage protocols, paramedics (ALS providers) can be spared and basic EMTs (basic life support [BLS] providers) are deployed directly to manage the cases [32]. In other situations, after an initial paramedic (ALS) response is made, the basic EMT ambulance can be called in to transport the less critical patients thus freeing up paramedics (ALS providers) for the more critical cases.

Not only does this type of system configuration permit the need for fewer ALS personnel, but it also improves response intervals because paramedics are not tied up transporting patients and are thus more available. Ironically, by having fewer paramedics, paramedic response can be improved [32].

Beyond on-scene procedures and moving the patient from the scene, the time to transport, provide hospital transition, create a record and then return to the primary response territory is the greatest deterrent to the availability of ambulance crews and thus a factor in compromised response times. Not surprisingly then, the original EMS systems reporting excellent paramedic track records with ETI were largely this type of tiered response system with staffing configurations that utilized basic EMTs for the majority of responses and spared the much smaller cadre of relatively busy paramedics for the more critical calls, therefore creating more opportunities for ETI skills usage [2,3,32,44].

Furthermore, the paramedics in these systems rapidly achieved experience seeing many dozens of cases per year and they eventually became reliably facile. In turn, as they became exceptionally facile, they deferred ETI attempts to new trainees. As a result, in these sophisticated EMS systems, the lesser-experienced medics rapidly developed their own skills even faster. Veterans also maintained their skills by teaching, supervising and getting to attempt and perform the more difficult intubations when the more novice personnel could not place the tube.

Unfortunately, today in the U.S. and other countries, the majority of EMS systems actually utilize all-paramedic (all-ALS) staffing on their ambulances. In addition, many first-responder crews often supplement ambulance response with additional paramedics (ALS providers) staffing the first response vehicles as well [26,28,33]. Therefore, it is no surprise that paramedics may not perform ETI as well as their forerunners 40 years ago.

Despite the described impact of using an all-paramedic system, one remedy might be to create a de facto ‘tier’ in those all-ALS systems by creating a team of supervisors, field training officers, or expert physician responders who routinely respond to critical calls. Depending upon the geography, vertical (high-rise) challenges, and traffic, it would be wise to create a small number of senior personnel who can respond across a designated territory (or even into a fellow senior officer’s territory for back-up) as a modified approach to ensure high level skills performance. Just as there may be 10 or so battalion fire chiefs in a city of a million residents spread out over a large geographical territory, staffing and responding a similar number of senior EMS personnel into high level cases could be another alternative and one that is now being adopted by many progressive EMS systems.

Expert on-scene supervision

Finally, even with appropriate, tailored initial training and tiered response systems with a high frequency of performance for individual paramedics, if the on-scene medics in training are not properly supervised, they may still develop bad habits in a vacuum. It is critical to reinforce what constitutes a proper technique (e. g., sniffing position in those at low risk of neck injury) and to provide renewed coaching in the actual patient care setting, especially in terms of confirmation of tube placement and proper ventilatory techniques. In most EMS systems that provide high rates of ETI success, in-field medical directors, highly-experienced EMS supervisors and well-coached veteran paramedics are the norm [2,6,12].

Why successful ETI attempts can even be detrimental

Detrimental effects of ventilatory techniques following intubation

Even if paramedics or other prehospital care providers are expertly trained, highly-skilled, highly-experienced and highly-supervised performers of intubation for both adults and children, their ventilatory techniques may still adversely affect outcome [25,37-39]. The types of patients most likely to need ETI are those with cardiac arrest, chronic lung disease and severe post-traumatic shock conditions. Yet these patients are also the most vulnerable to the detrimental cardiovascular effects of the positive pressure breaths that are being delivered through the ETT [39].

Despite the basic physiological principle that ventilation should match perfusion (blood flow), over the years, in many venues, EMS personnel have been trained traditionally to aggressively ventilate patients, usually with the ill-advised rationale that such an approach was the way to ensure oxygenation and offset metabolic acidosis [37,38]. Even with more judicious training, however, emergency workers can still have the tendency to over-zealously ventilate such patients in the heat of the emergency [38]. Ironically, while such patients in deep shock actually require infrequent breaths and a lesser minute ventilation, once the ETT is placed, they may now receive excessive levels of assisted breathing, not only because of some unsound rote training, but also because of adrenaline-modulated behaviors [38].

Accordingly, it is now speculated that low national survival rates for out-of-hospital cardiac arrest and the negative outcomes of several prehospital clinical trials may have been, in part, the result of uncontrolled ventilatory rates using positive pressure breaths [39]. For example, in the study of severe traumatic brain injury (TBI) in which RSI-facilitated ETI was associated with worse outcomes, a key correlation with mortality was the finding "hyperventilation", defined as an arterial $PCO_2 < 24$ mmHg [25]. While one might suspect that these negative outcomes may, therefore, be caused by effects of respiratory alkalosis, such as myocardial depression, cerebral vasoconstriction and a left shift in the hemoglobin dissociation curve, it is most likely that the low arterial PCO_2 is simply a surrogate variable for overzealous positive pressure ventilation [37-39].

As Aufderheide and colleagues have shown, despite aggressive, targeted re-training on respiratory rates and delivery techniques, paramedics still overzealously ventilate and prolong the duration of positive pressure breaths in the adrenaline-charged environment of a critical emergency [38]. It is likely that this scenario is exaggerated in children, considering that paramedics and other emergency care providers are trained to think that pediatric arrests are mostly the result of hypoxemia and that proscribed respiratory rates are generally higher than those proscribed for adults [19,26,39]. Also, emotions run even higher in childhood critical emergencies, theoretically compounding any predisposition to overzealously ventilate. Therefore, clinical trials that indicated worse outcomes with ETI may have been confounded by unrecognized detrimental ventilatory techniques [37-39].

So, paradoxically, in systems where many paramedics are deployed to *all* prehospital emergency cases with the rationale of improving response times for ALS procedures (and thus improved survival chances), worse outcomes might actually be expected, especially with successful ETI. In the EMS system in which the clinical trial of pediatric intubation was conducted [26], more than 2000 paramedics were trained to perform what resulted in being less than 150 annual pediatric intubations across the system during the study period.

Experience-wise, this type of system configuration issue makes it difficult for the individual paramedic to get much exposure, even to adult intubations. Clearly, pediatric intubation situations would be uncommon, or even unlikely over his or her entire career. This is a set-up for misplaced tubes or significantly delayed ETI. It also means too frequent and too lengthy pauses in chest compressions if the crews are not facile at placing the tube. Overall, this scenario provides a clear set-up for under-skilled attempts at ETI altogether [2,32]. Coupled with high anxiety when dealing with kids, an EMS system that follows typical protocols for ventilation and/or does not control for overzealous ventilation, may likely experience even poorer outcomes.

Under these circumstances, one can make a strong argument against using ETI or attempting ETI, especially in children and other vulnerable groups such as spontaneously-breathing head injured patients. Nevertheless, it must be kept in mind that there are communities that can safely enjoy high success rates for ETI and associated good outcomes for patients, even using certain RSI techniques [3,7,8,21,46]. But, again, these EMS systems are typified by street-wise training, tiered paramedic ambulance response systems, and patient care protocols involving controlled ventilatory techniques for critical cases. Places like Houston and Seattle in the 1980s were delivering only one positive pressure breath every ten seconds to their patients with circulatory arrest and outcomes were exceptional when compared to other sites [3,7,8,21].

Most importantly, these sites also involved intensive on-scene expert medical oversight [2,12,46]. Therefore, ETI should not be discouraged in such appropriate settings. On the other hand, as other researchers have implied, ETI and/or RSI should be discouraged in those EMS systems that are unable to adapt to those appropriate characteristics that facilitate ETI and its proper use.

Conclusion

While ETI remains the gold standard for definitive airway management in the emergency care setting, it may beinappropriate in the prehospital setting in the absence of paramedic-sparing deployment systems, controlled ventilatorytechniques and intensive medical oversight that provides street-wise training as well as expert, on-scene supervision of theEMS personnel providing the ETI. While ETI may very well be life-saving, particularly in cases of severe trauma withcirculatory arrest, ETI may also be detrimental in certain EMS systems. Successful placement and use of an ETI is morelikely to occur in EMS systems that provide:

1) 'street-wise' training that is provided by experts in out-of-hospital patient care who themselves are well-experienced in on-scene emergency ETI;
2) tiered EMS deployment systems that spare a small cadre of highly-skilled (and relatively busy) paramedics from the majority of EMS incidents (focusing them on the more critical cases, thus resulting in a very high frequency of ETI performance by each individual in the system); and
3) intensive, street-wise and expert out-of-hospital medical oversight.

But, even when paramedics (and other ALS providers) are facile at ETI in the unique environmental conditions and challenges of the out-of-hospital setting, inappropriate and overzealous ventilation can still result in detrimental outcomes. In summary, systems unable to adopt the appropriate configurations, protocols, training, monitoring, and all other characteristics that optimize ETI may, therefore, need to be discouraged from performing ETI or they need to develop alternative mechanisms to better ensure routine success with placement of the tube and its appropriate use.

Abbreviations

ALS: Advanced life support; BLS: Basic life support; BVM: Bag-valve-mask; CPR: Cardiopulmonary resuscitation; EKG: Electrocardiographic; EMS: Emergency medical services; EMT: Emergency medical technician; ETI: Endotracheal intubation; ETT: Endotracheal tube; ICU: Intensive care unit; i.v.: Intravascular; RSI: Rapid sequence induction; TBI: Traumatic brain injury.

Competing interests

The authors declare that they have no competing interests.

Declarations

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References

1. Pantridge JF, Geddes JS. A mobile intensive care unit in the management of myocardial infarction. Lancet. 1967;290:271–3.
2. Cobb LA, Alvarez H, Copass MK. A rapid response system for out-of-hospital cardiac emergencies. Med Clin North Am. 1976;60:283–93.
3. McManus WF, Tresch DD, Darin JC. An effective prehospital emergency system. J Trauma. 1977;17:304–10.
4. Jacobs LM, Berrizbeitia LD, Bennett B, Madigan C. Endotracheal intubation in the prehospital phase of emergency medical care. JAMA. 1983;250:2175–7.
5. Pepe PE, Copass MK, Joyce TH. Prehospital endotracheal intubation: rationale for training emergency medical personnel. Ann Emerg Med. 1985;14:1085–92.
6. Stewart RD, Paris P, Winter PM, et al. Field endotracheal intubation by paramedical personnel: success rates and complications. Chest. 1984;85:341–5.
7. Copass MK, Oreskovich MR, Blaedogroen MR, Carrico CJ. Prehospital cardiopulmonary resuscitation of the critically injured patient. Am J Surg. 1984;148:20–4.
8. Durham LA, Richardson RJ, Wall MH, Pepe PE, Mattox KL. Emergency center thoracotomy: impact of prehospital resuscitation. J Trauma. 1992;32:775–9.
9. Miller JD, Sweet RC, Narayan R, Becker DP. Early insults to the injured brain. JAMA. 1978;240:439–42.
10. Page JO. The paramedics: an illustrated history of paramedics in their first decade in the U.S.A. Morristown, New Jersey, USA: Backdraft Publications; 1979. p. 1–179.
11. American College of Surgeons Committee on Trauma. Advanced trauma life support program for physicians. 6th ed. Chicago: American College of Surgeons; 1997. p. 21–124. Chapters 1–3.
12. Pepe PE, Copass MK, Fowler RL, Racht EM. Medical direction of emergency medical services systems. In: Cone DC, Fowler R, O'Connor RE, editors. Textbook of the National Association of EMS Physicians. Dubuque, Iowa, USA: Kendall Hunt Publications; 2009. p. 22–52.
13. Warner KJ, Carlbom D, Cooke CR, Bulger EM, Copass MK, Sharar SR. Paramedic training for proficient prehospital endotracheal intubation. Prehospital Emerg Care. 2010;14:103–8.
14. Sirbaugh PE, Pepe PE, Shook JE, et al. A prospective, population-based study of the demographics, epidemiology, management and outcome of out-of-hospital pediatric cardiopulmonary arrest. Ann Emerg Med. 1999;33:174–84.
15. Winchell RJ, Hoyt DB. Endotracheal intubation in the field improves survival in patients with severe head injury. Arch Surg. 1997;132:592–7.
16. Eckstein M, Chan L, Schneir A, Palmer R. The effect of prehospital advanced life support on outcomes of major trauma patients. J Trauma. 2000;48:643–8.
17. Hasegawa K, Hiraide A, Chang Y, Brown DF. Association of prehospital advanced airway management with neurologic outcome and survival in patients with out-of-hospital cardiac arrest. JAMA. 2013;309:257–66.
18. Holmberg M, Holmberg S, Herlitz J. Low chance of survival among patients requiring adrenaline (epinephrine) or intubation after out-of-hospital cardiac arrest in Sweden. Resuscitation. 2002;54:37–45.
19. Atkins DL, Everson-Stewart S, Sears GK, Daya M, Osmond MH, Warden CR. Epidemiology and outcomes from out-of-hospital cardiac arrest in children: the Resuscitation Outcomes Consortium Epistry-Cardiac Arrest. Circulation. 2009;119:1484–91. for the Resuscitation Outcomes Consortium.
20. Hanif MA, Kaji AH, Niemann JT. Advanced airway management does not improve outcome of out-of-hospital cardiac arrest. Acad Emerg Med. 2010;17:926–31.
21. Key CB, Pepe PE, Sirbaugh PE, Shook JE, Kimball KT. Does endotracheal intubation affect outcome in out-of-hospital pediatric cardiac arrest? Acad Emerg Med. 1996;3:404–5.
22. Wang HE, Yealy DM. Out-of-hospital endotracheal intubation: where are we? Ann Emerg Med. 2006;47:532–41.
23. Strote J, Roth R, Cone DC, Wang HE. Prehospital endotracheal intubation: the controversy continues. Am J Emerg Med. 2009;27:1142–7.
24. Lossius HM, Sollid SJM, Rehn M, Lockey DJ. Revisiting the value of pre-hospital tracheal intubation: an all-time systematic literature review extracting the Utstein airway core variables. Crit Care. 2011;15:R26.
25. Davis DP, Hoyt DB, Ochs M, et al. The effect of paramedic rapid sequence intubation on outcome in patients with severe traumatic brain injury. J Trauma. 2003;54:444–53.
26. Gausche M, Lewis RJ, Stratton S, et al. Effect of out-of-hospital pediatric endotracheal intubation on survival and neurological outcome. JAMA. 2000;283:783–90.
27. Pepe PE, Eckstein M. Reappraising the prehospital care of the patient with major trauma. Emerg Med Clin N Am. 1998;16:1–15.

28. Katz SH, Falk JL. Misplaced endotracheal tubes by paramedics in an urban emergency medical services systems. Ann Emerg Med. 2001;37:32–7.
29. Wang HE, Kupas DF, Paris PM, et al. Preliminary experience with a prospective, multi-centered evaluation of out-of-hospital endotracheal intubation. Resuscitation. 2003;58:49–58.
30. Christenson J, Andrusiek D, Everson-Stewart S, Kudenchuk P, Hostler D, Powell J. Chest compression fraction determines survival in patients with out-of-hospital ventricular fibrillation. Circulation. 2009;120:1241–7.
31. Bobrow BJ, Clark LL, Ewy G, et al. Minimally interrupted cardiac resuscitation. JAMA. 2008;299:1158–65.
32. Curka PA, Pepe PE, Ginger VF, Ivy MV, Sherrard RC, Zachariah BS. Emergency medical services priority dispatch. Ann Emerg Med. 1993;22:1688–95.
33. Stout J, Pepe PE, Mosesso VN. All-advanced life support versus tiered-response ambulance systems. Prehospital Emerg Care. 2000;4:1–6.
34. Pepe PE, Zachariah BS, Chandra N. Invasive airway techniques in resuscitation. Ann Emerg Med. 1993;22(Part II):393–403.
35. Silvestri S, Ralls G, Krauss B, et al. The effectiveness of out-of-hospital use of continuous end-tidal carbon dioxide monitoring on the rate of unrecognized misplaced intubation within a regional emergency medical service system. Ann Emerg Med. 2005;45:497–503.
36. Burton JH, Baumann MR, Maoz T, et al. Endotracheal intubation in a rural state: Procedure utilization and impact of skills maintenance guidelines. Prehospital Emerg Care. 2003;7:352–6.
37. Pepe PE, Lurie KG, Wigginton JG, Raedler C, Idris AH. Detrimental hemodynamic effects of assisted ventilation in hemorrhagic states. Crit Care Med. 2004;32(Suppl):414–20.
38. Aufderheide TP, Sigurdsson G, Pirrallo RG, et al. Hyperventilation-induced hypotension during cardiopulmonary resuscitation. Circulation. 2004;109:1960–5.
39. Roppolo LP, Wigginton JG, Pepe PE. Emergency ventilatory management as a detrimental factor in resuscitation practices and clinical research efforts. In: Vincent JL, editor. 2004 Intensive Care and Emergency Medicine. Berlin: Springer-Verlag; 2004. p. 139–51.
40. Bernhard M, Becker TK, Böttiger BW. Prehospital airway management for out-of-hospital cardiac arrest. JAMA. 2013;309:1888.
41. Wang HE, Balasubrami GK, Lave JR, et al. Paramedic endotracheal intubation experience improves patient survival. Prehosp Emerg Care. 2009;19:90–1.
42. Helm M, Hossfeld B, Schafer S, Hoitz J, Lampl L. Factors influencing emergency intubation in the pre-hospital setting – a multicentre study in the German helicopter emergency medical service. Br J Anaesthesia. 2005;96:67–71.
43. Jensen JL, Cheung KW, Tallon JM, Travers AH. Comparison of tracheal intubation and alternative airway techniques performed in the prehospital setting by paramedics: a systematic review. Can J Emerg Med. 2010;12:135–40.
44. Wang HE, Szydlo D, Stouffer JA, Lin S, Carlson JN, Vaillancourt C. Endotracheal intubation versus supraglottic airway insertion in out-of-hospital cardiac arrest. Resuscitation. 2012;83:1061–6.
45. Pepe PE, Mattox KL, Fischer RP, Matsumoto CM. Geographical patterns of urban trauma according to mechanism and severity of injury. J Trauma. 1990;30:1125–32.
46. Persse DE, Key CB, Bradley RN, et al. Cardiac arrest survival as a function of ambulance deployment strategy in a large urban medical services system. Resuscitation. 2003;59:97–104.