Prehospital trauma care: what do we really know?

Moishe Liberman[a] and Bahman S. Roudsari[b]

Purpose of review

The prehospital care of injured patients has been surrounded with much controversy over the years. This controversy exists regarding the specific interventions used on-scene and en-route to definitive care centers, regarding the overall approach to the care of these patients (advanced life support versus basic life support) and with regards to who should be providing this care. This section of the journal aims to review the most current literature concerning these topics as well as highlight some important and relevant literature preceding it.

Recent findings

Studies examining overall prehospital care in terms of morbidity, mortality and cost have been published over the last year and important points from these studies are highlighted in the text. Unfortunately, there have not been any recent, appropriately powered, prospective studies that help in clarifying this controversy. An international study of prehospital care has recently been completed and is summarized. Recent studies looking at specific aspects of prehospital care (endotracheal intubation, intravenous access and therapy, rural trauma) are also outlined in the text.

Summary

There is no convincing evidence that prehospital advanced life support in the urban setting provides any benefit to injured patients in terms of either morbidity or mortality.

Keywords

ALS, BLS, emergency medical technician, paramedic, prehospital, trauma

Curr Opin Crit Care 13:691–696.

[a]Department of Surgery, Montreal General Hospital, McGill University, Montreal, Quebec, Canada and [b]School of Public Health, University of Texas, Dallas, Texas, USA

Correspondence to Moishe Liberman, MD, Montreal General Hospital, McGill University Health Centre, 1650 Cedar Avenue, L9-512, Montreal, Quebec, H3G 1A4, Canada
Tel: +1 514 934 1934; fax: +1 514 937 5522; e-mail: moishe.liberman@mcgill.ca

Current Opinion in Critical Care 2007, 13:691–696

Abbreviations

ALS advanced life support
BLS basic life support
EMS emergency medical services
EMT emergency medical technicians
ETI endotracheal intubation
ISS Injury Severity Score

1070-5295

Introduction

Prehospital transport and care of injured patients is paramount to an effective and efficient system of trauma care. Transport occurs by ground ambulance [1–7], by air [8–10], by bystanders [11,12] and even by taxi [12]. Yet prehospital care of injured patients has been surrounded by much controversy [13,14]. This controversy involves the appropriate care of the trauma patient on-scene and en-route to the treatment facility and the evidence regarding the superiority of either system has often been insufficient and contradictory [15–18,19•,20•].

The unresolved controversy and division of opinion regarding the on-site management of trauma patients is reflected in the regional variation of prehospital patient management protocols. The type of prehospital care available to trauma patients is determined by regional policies that are dictated by local political, cultural and economic factors as well as the influential opinion of local and international experts. The evidence for direct transport of injured patients to advanced level, 'definitive-care' centers, bypassing closer hospitals, has been well studied, established and accepted [21–26]. This has recently been re-evaluated and again affirmed in a cohort of patients with severe traumatic brain injury in New York [27].

Lerner *et al.* [28•] recently undertook an economic evaluation of prehospital emergency care through meta-analysis and were unable to firmly associate cost-effectiveness for most aspects of prehospital care. In a recent small before-and-after study from Finland, Iirola *et al.* [29•] compared outcomes of similar injury severity blunt trauma patients treated in the prehospital setting by physician-staffed helicopters ($n = 81$) with expanded basic life support (BLS) treated patients ($n = 77$) from the era prior to helicopter advanced life support (ALS) introduction. ALS treated patients received more interventions and were more often transported directly to a university hospital. There was a trend to lower survival in the helicopter-ALS group (31% ALS versus 18% BLS). At 3 years following injury, there was no difference in quality of life or income between the two groups.

Karanicolas *et al.* [30] recently performed an interesting analysis comparing land with helicopter transport of blunt trauma patients between hospitals in London, Ontario, Canada. They showed that the time associated with transfer was dependant on factors other than distance and that the time between decision to transfer and arrival at the trauma center for patients transferred by land was faster than for those transferred by air (120 versus 150 min).

In a recent study out of Temple University in Philadelphia, Seamon *et al.* [31••] looked at mortality outcomes for trauma patients who underwent emergency department thoracotomy following arrival at hospital. They divided patients into two groups based on their mode of transportation to the hospital. Eighty-eight patients were transported to hospital by paramedics (emergency medical services; EMS) and 92 were transported by bystanders or police (non-EMS). Eight percent of EMS-transported patients survived to hospital discharge compared with 17.4% of non-EMS transported patients. Eighty-nine percent of patients in the EMS group underwent prehospital procedures and the performance of prehospital procedures was the only risk factor associated with increased mortality on multivariate analysis. Each prehospital procedure performed was associated with an increased chance of dying by 2.63. Patients undergoing emergency department thoracotomy are obviously severely injured and the Injury Severity Scores (ISSs) for the two groups were high. Interestingly, the EMS-transported patients had significantly lower ISS (EMS, 35; non-EMS, 44) and a higher percentage of patients exhibited signs of life in the field (EMS, 83%; non-EMS, 69%) compared with the non-EMS transported patients.

Prehospital time

One of the key principles in trauma patient management is that of the 'golden hour' or 'golden period.' This period is defined as the immediate time after injury when resuscitation and stabilization will be most beneficial to the patient [32]. As time passes following most critical trauma, tissue hypoxia increases and the chance of survival or chance of good postsurvival prognosis decreases [11,33,34]. In all trauma patients it is critical to balance the need for prehospital care and the need for prompt transport of the patient to hospital for definitive care. A prehospital time period of greater than 60 min (the so-called golden hour [35]) has been associated with a significant increase in the risk of death for severely injured patients [4]. It should be noted, however, that this 1-h cut-off has not been scientifically replicated and its usefulness for EMS planning has been called into question [36].

Baez *et al.* [37•] recently reported on prehospital times and outcome in a large database cohort of severely injured trauma patients. They found that in patients with ISS over 15, longer prehospital time was associated with increased length of stay and complications, but was not associated with increased mortality.

Intravenous initiation and fluid therapy

In addition to increasing prehospital delays, the argument against 'stay and stabilize' is strengthened because none of the specific ALS interventions has been proven to be beneficial for the prehospital management of severely injured patients. The rationale for using on-site intravenous line placement and fluid infusion is that it will control hemodynamic deterioration. The amount of fluid infused, however, cannot compensate for the blood lost in a severely bleeding patient; for such cases the definitive treatment is surgery [38–40]. The time required to start an intravenous on the scene is a matter of debate with certain authors reporting minimal times between 2 and 4 min [3,41–45] while others show times of 12 min or more [46,47]. There are no prospective controlled studies evaluating the impact of intravenous placement on patient outcome.

The intravenous cannulation success rates have been shown to be over 90% in the prehospital setting, unfortunately the average volumes of fluids being given in the prehospital setting are very low (mean intravenous fluid infused 959.6 ± 309.1 ml in 14 studies providing prehospital intravenous fluid volume data) [16]. We must ask ourselves whether the increased time required to insert intravenous cannulae in hypotensive trauma patients in the field is actually beneficial, seeing that patients are receiving on average less than 1 l of fluid prior to hospital arrival. Minville *et al.* [48] recently reported a 4.4 min on-scene time for successful intravenous placement in a cohort of 388 patients in France. The intravenous cannulation success rate was 76% on the first attempt and 98% on the second attempt (overall success rate, 99.7%; attempt range, 1–8).

The infusion of crystalloid or hypertonic saline into a patient with ongoing hemorrhage has been shown to be detrimental to patients in both animal [49–55] and human models [56,57]. This is probably secondary to dilution of clotting factors and platelets, dropping of the hematocrit and decreasing patient temperature. It also increases the blood pressure of a patient with ongoing hemorrhage, leading to further bleeding and decreasing the chance of clot formation at the site of blood loss. Filling a patient's circulatory system with nonoxygen carrying fluids, which have decreased clotting ability prior to fixing the hole in the system is counterintuitive and is the probable cause for the inferior outcomes seen in the aforementioned studies of penetrating injuries.

The Cochrane Review group examined all randomized trials of the timing and volume of intravenous fluid administration in bleeding trauma patients. They did not find any evidence supporting or refuting early or large volume fluid administration in patients with uncontrolled hemorrhage [58].

Endotracheal intubation

We are reminded that even in our highly advanced and technical society, that the most precious commodity in the treatment of the trauma patient is time. In the past, there have been a number of papers demonstrating a negative effect, or lack of effect, of prehospital endotracheal intubation (ETI) on survival and neurological outcome [59–61]. Prehospital ETI has never been shown to improve neurologic outcome. Eckstein *et al.* [62] reported on outcomes of patients receiving prehospital ALS compared with those who did not. Patients who did not undergo prehospital intubation had a greater than five times increased odds of survival compared with those that underwent the procedure. On-scene time was not prolonged by performing ALS techniques, which suggests a deleterious effect of the intervention not related to time. A prospective clinical trial performed in the pediatric population also demonstrated a lack of benefit for prehospital intubation in terms of survival and neurological outcome [63]. The controversy regarding prehospital ETI is well delineated in a recent review by Wang and Yealy [64••].

Similar to intravenous placement, the effectiveness of on-site intubation in improving outcome of severely injured patients has not been adequately evaluated. The rationale for on-scene intubation is that this intervention will maintain airway patency and oxygenation [65]. As with intravenous placement, the argument against intubation is that it causes significant delays to definitive in-hospital care. Contrary to intravenous placement, however, there is some agreement that in certain severely injured and unconscious patients intubation should be initiated at the scene or en-route [65–67]. This has not, however, been based on evidence and is mostly expert opinion. Hoyer *et al.* [68] recently reported an increase in prehospital scene time by 7.5 min in patients receiving on-site ETI by anaesthesiologists in Denmark. Fakhry *et al.* [69] reported a similar increase in scene time with on-scene rapid sequence intubation (RSI) of 6 min in head trauma patients. The success rate for on-scene RSI was 96.6% in this study. Helm *et al.* [70] reported on the safety of prehospital ETI in Germany. He demonstrated a 100% success rate after three attempts (87.4% first attempt; 11.1% second attempt; 1.5% third attempt).

Warner *et al.* [71] looked at the impact of prehospital ventilation on outcome. Patients in this study were prospectively enrolled and consisted of all patients endotracheally intubated in the field and directly transported to a level I trauma center ($n = 423$). P_{CO2} on arrival was used as a surrogate for prehospital ventilation status ($P_{CO2} < 30$ hyperventilation; $P_{CO2} = 30–35$ target ventilation; P_{CO2} 36–45, mild hypercapnea). Patients with severe hypercapnea ($P_{CO2} > 45$) were excluded. Results demonstrated that patients in the target ventilation range had the lowest risk of death (OR = 0.54, 95% CI, 0.32–0.90) compared with the other groups. Patients with severe head injury (head Abbreviated Injury Scale >3) in the target range had an odds ratio of 0.51 (95% CI 0.25–1.0), and for isolated traumatic brain injury the odds ratio for patients in the target range was 0.31 (95% CI 0.10–0.96). This was an important study looking at targeted ventilation in the prehospital setting. It, however, does not allow differentiation between over or under-ventilation in the prehospital phase and severity of injury causing hypercapnea. It also lacks comparison to a noninvasive ventilation strategy (bag–valve–mask ventilation), which may permit similar admission P_{CO2} measurements without the attendant risks of ETI (airway trauma, esophageal intubation, loss of airway following paralysis, hypoxia during failed intubation attempts, increased on-scene time).

Tracy *et al.* [72] looked at outcome following emergency intubation, comparing prehospital intubation ($n = 271$) with trauma center intubation ($n = 357$). They were unable to demonstrate any difference in incidence, onset or bacteriology of pneumonia between groups.

Airway management is a key, but somewhat unaddressed issue in prehospital trauma care literature. There has been little evidence examining various intubation techniques in the prehospital setting. Some issues which remain unresolved include the technique used for intubation, the size of tubes being used in children and adolescents, the rates of recognized and unrecognized esophageal and left mainstem intubations in the field. The most important question, however, remains whether this intervention is actually beneficial and worth the added on-scene time for injured patients.

Urban versus rural systems

Are we able to group urban and rural systems into one category when discussing prehospital ALS for trauma? Could prolonged transport times be associated with increased benefit with advanced on-scene interventions? Messick and Meyer [73] showed that mean trauma death rates in rural BLS counties was 8.2 ± 2.2 versus 6.1 ± 1.3 in rural ALS counties ($P = 0.0001$). This may simply be driven by the innate situation within which rural prehospital providers find themselves: difficulties in finding call addresses, longer distances, and fewer, if any trauma centers.

Carr *et al.* [74•] recently published a meta-analysis of EMS transport times for trauma which showed that scene times in rural areas were about 12% longer than those in urban areas and that the overall prehospital period was almost one-third longer in rural than in urban areas. Total prehospital times for urban, suburban and rural areas were 31, 31 and 43 min respectively. On-scene times were similar between groups: 14, 14 and 15 min respectively.

ALS may be beneficial to patients with prolonged prehospital transport times. A patient with prolonged hypotension may suffer end organ damage secondary to prolonged inadequate perfusion and suffer long-term effects from organ injury. Unfortunately, to date, we do not have evidence supporting the implementation of ALS in rural areas. Furthermore, since the incidence of trauma is low in rural compared with urban areas and due to the fact that ALS is extremely expensive compared with BLS [75], even if ALS is shown to benefit rural trauma patients, it may not be cost effective.

International prehospital trauma care

One of the main limitations in prehospital trauma care research is the difficulty in the conduction of randomized clinical trials due to logistic or ethical issues. Researchers have therefore traditionally relied on observational studies. Another important issue in prehospital trauma care research is that EMS systems adopt different policies reflecting their specific demographics, capabilities and population served. The system adopted is applied to all patients receiving care within the specific system. For example, if an EMS system adopts an ALS policy, emergency medical technicians (EMTs) provide ALS to all trauma patients whose medical condition is deemed appropriate for advanced level care. Thus, in order to evaluate the effectiveness of ALS on trauma fatality rate, we must compare patient outcomes in an ALS EMS system with patient outcomes in a BLS system. Under this circumstance, we are actually comparing outcomes of the clusters of patients nested within EMS systems. Therefore, data from several EMS systems with ALS capabilities and several systems with BLS capabilities are required in order to evaluate the association between an ALS or BLS policy and trauma fatality rate. We have recently demonstrated how clustering the patients within EMS systems can influence study design and data analysis [76]. Specifically, it has been demonstrated that there exists a false significant association between exposure and outcome secondary to overlooking clustering in design of studies.

The authors recently conducted an international study which compared the three major types of EMS systems: BLS, ALS with EMTs as care providers and ALS with physicians as care providers (Doc-ALS) [77•,78•]. Data from local or national trauma registries of Australia (ALS), Austria (Doc-ALS), Canada (two regions, BLS and Doc-ALS), Greece (Doc-ALS), Germany (Doc-ALS), Iran (BLS), Mexico (BLS), New Zealand (ALS), the Netherlands (ALS), the United Kingdom (two regions, ALS and Doc-ALS) and the United States (ALS) were used in this study [77•]. The most striking finding was the substantial heterogeneity in the performance of EMS systems with the same prehospital trauma care policy. For example, the use of intravenous fluid therapy among ALS EMS systems varied from 30% (in the Netherlands) to 55% (in the US). The corresponding percentages in Doc-ALS EMS systems, excluding Montreal in Canada, ranged from 63% (in London, UK) to 75% in Germany and Austria. Austria and Germany also reported the highest percentage of prehospital intubation (61% and 56%, respectively).

Using generalized linear latent and mixed models that took into consideration the clustering of the subjects within EMS systems, it was demonstrated that the emergency department shock rate did not vary significantly between Doc-ALS and ALS systems (OR 1.16; 95% CI 0.73–1.91). The early trauma fatality rate was significantly lower in Doc-ALS EMS systems compared with ALS EMS systems (OR 0.70; 95% CI 0.54–0.91) [78•].

Conclusion

There is no convincing evidence that prehospital ALS in the urban setting provides any benefit to injured patients in terms of either morbidity or mortality. A recent Cochrane Review concluded that 'in the absence of evidence of the effectiveness of advanced life support, strong argument could be made that it should not be promoted outside the context of a properly concealed and otherwise rigorously conducted randomized controlled trial' [79]. To date, there has never been a prospective, randomized trial comparing ALS with BLS for victims of trauma in the prehospital setting. This is long overdue.

Acknowledgement

Moishe Liberman is supported by a fellowship award from the Canadian Institute of Health Research (CIHR).

References and recommended reading

Papers of particular interest, published within the annual period of review, have been highlighted as:

- • of special interest
- •• of outstanding interest

Additional references related to this topic can also be found in the Current World Literature section in this issue (p. 760).

1 Grossman DC, Kim A, Macdonald SC, *et al.* Urban–rural differences in prehospital care of major trauma. J Trauma 1991; 42:723–729.

2 Liberman M, Mulder D, Lavoie A, *et al.* Multicentre Canadian study of prehospital trauma care. Ann Surg 2003; 237:153–160.

3 O'Gorman M, Trabulsy P, Pilcher DB. Zero-time prehospital IV. J Trauma 1989; 29:84–86.

4 Sampalis JS, Lavoie A, Williams JI, *et al.* Impact of on-site care, prehospital time, and level of in-hospital care on survival in severely injured patients. J Trauma 1993; 34:252–261.

5 Sampalis JS, Tamim H, Denis R, *et al.* Ineffectiveness of on-site intravenous lines: Is prehospital time the culprit? J Trauma 1997; 43:608–617.

6 Trunkey DD. Is ALS necessary for prehospital trauma care? [editorial]. J Trauma 1984; 24:86.

7 Sampalis JS, Tamim H, Nikolis A, *et al.* Predictive validity and internal consistency of the prehospital index measured on-site by physicians. Accid Anal and Prev 1996; 28:675–684.

8 Ornato JP, Craren EJ, Nelson NM, Kimball KF. Impact of improved emergency medical services and emergency trauma care on the reduction in mortality from trauma. J Trauma 1985; 25:575–579.

9 Schwab CW, Peclet M, Zackowski SW, *et al.* The impact of an air ambulance system on an established trauma center. J Trauma 1985; 25:580–586.

10 Baxt WG, Moody P. The impact of a rotorcraft aeromedical emergency care service on trauma mortality. JAMA 1983; 249:3047–3051.

11 Cornwell EE 3rd, Belzberg H, Hennigan K, *et al.* Emergency medical services (EMS) versus non-EMS transport of critically injured patients. Arch Surg 2000; 135:315–319.

12 Demetriades D, Chan L, Cornwell E, *et al.* Paramedic vs private transportation of trauma patients. Arch Surg 1996; 131:133–138.

13 Fowler R, Pepe PE. Prehospital care of the patient with major trauma. Emerg Med Clin N Am 2002; 20:953–974.

14 Blackwell T. Principles of emergency medical services systems. In: Marx JA, Hockberger RS, Walls RM, Adams JG, editors. Rosen's Emergency medicine: concepts and clinical practice. St. Louis: Mosby; 2002. pp. 2616–2625.

15 Lockey DJ. Prehospital trauma management. Resuscitation 2001; 48:5–15.

16 Liberman M, Mulder D, Sampalis JS. Advanced or basic life support for trauma: meta-analysis and critical review of the literature. J Trauma 2000; 49:584–599.

17 Spaite DW, Criss EA, Vaenzuela TD, Meislin HW. Prehospital advanced life support for major trauma: critical need for clinical trials. Ann Emerg Med 1998; 32:480–489.

18 Callaham M. Quantifying the scanty science of prehospital care. Ann Emerg Med 1997; 30:785–790.

19 • Burton JH. Out-of-hospital endotracheal intubation: half empty or half full? Ann Emerg Med 2006; 47:542–544.
This is an editorial on prehospital ETI.

20 • Berlot G, Bacer B, Gullo A. Controversial aspects of the prehospital trauma care. Crit Care Clin 2006; 22:457–468.
This is a review paper regarding a controversial aspect of prehospital care.

21 West JG, Cales RH, Gazzaniga AB. Impact of regionalization. The Orange County experience. Arch Surg 1983; 118:740–744.

22 West JG, Trunkey DD, Lim RC. Systems of trauma care. A study of two counties. Arch Surg 1979; 114:455–460.

23 Sampalis JS, Denis R, Frechette P, *et al.* Direct transport to tertiary trauma centers versus transfer from lower level facilities: impact on mortality and morbidity among patients with major trauma. J Trauma 1997; 43:288–296.

24 Liberman M, Mulder DS, Lavoie A, Sampalis JS. Implementation of a trauma care system: evolution through evaluation. J Trauma 2004; 56:1330–1335.

25 Liberman M, Mulder DS, Sampalis JS. The evidence supporting a systematic approach to the care of the injured patient: from prevention to rehabilitation; MJM Focus: Special Forum on Trauma Care. McGill Journal of Medicine 2004; 7:223–237.

26 Liberman M, Mulder DS, Sampalis JS. The history of trauma care systems: from Homer to telemedicine; MJM Focus: Special Forum on Trauma Care. McGill Journal of Medicine 2004; 7:124–222.

27 Hartl R, Gerber LM, Iacono L, *et al.* Direct transport within an organized state trauma system reduces mortality in patients with severe traumatic brain injury. J Trauma 2006; 60:1250–1256.

28 • Lerner EB, Maio RF, Garrison HG, *et al.* Economic value of out-of-hospital emergency care: a structured literature review. Ann Emerg Med 2006; 47:515–524.
Economic evaluation of prehospital emergency care through meta-analysis. No cost-effectiveness for most aspects of prehospital care was demonstrated.

29 • Iirola TT, Laaksonen MI, Vahlberg TJ, *et al.* Effect of physician-staffed helicopter emergency medical service on blunt trauma patient survival and prehospital care. Eur J Emerg Med 2006; 13:335–339.
Comparison of outcomes of similar injury severity blunt trauma patients treated in the prehospital setting by physician-staffed helicopters with patients treated using BLS. There was a trend to lower survival in the helicopter-ALS group.

30 Karanicolas PL, Bhatia P, Williamson J, *et al.* The fastest route between two points is not always a straight line: an analysis of air and land transfer of nonpenetrating trauma patients. J Trauma 2006; 61:396–403.

31 •• Seamon MJ, Fisher CA, Gaughan J, *et al.* Prehospital procedures before emergency department thoracotomy: 'scoop and run' saves lives. J Trauma 2007; 63:113–120.
This study described mortality outcomes for trauma patients who underwent emergency department thoracotomy following arrival at hospital. Patients were divided into two groups based on their mode of transportation to the hospital (paramedic versus bystander/police). Mortality was double for paramedic transported patients.

32 Boyd DR, Cowley RA. Comprehensive regional trauma/emergency medical services (EMS) delivery systems. World J Surg 1983; 7:149–157.

33 Rady MY. Triage and resuscitation of critically ill patients in the emergency department: current concepts and practice. Eur J Emerg Med 1994; 175:189.

34 Rady MY. Triage of critically ill patients: an overview of interventions. Emerg Med Clin North Am 1996; 14:13–33.

35 Cowley RA. A total emergency medical system for the state of Maryland. Maryland State Med J 1975; 24:37–45.

36 Lerner EB, Moscati RM. The golden hour: scientific fact or medical 'urban legend'? Acad Emerg Med 2001; 8:758–760.

37 • Baez AA, Lane PL, Sorondo B, *et al.* Predictive effect of out-of-hospital time in outcomes of severely injured young adult and elderly patients. Prehosp Disaster Med 2006; 21:427–430.
This study described prehospital times and outcome in a large database cohort of severely injured trauma patients. In patients with ISS>15, longer prehospital time was associated with increased length of stay and complications, but was not associated with increased mortality.

38 Trunkey DD, Siegel J, Baker SP, Gennarelli TA. Panel: Current status of trauma severity indices. J Trauma 1983; 23:185–201.

39 Gold CR. Prehospital advanced life support vs 'scoop and run' in trauma management. Ann Emerg Med 1987; 16:797–801.

40 Trunkey DD. Trauma. Sci Am 1983; 249:28–35.

41 Cwinn AA, Pons PT. On-scene management of trauma patients by paramedics. Ann Emerg Med 1998; 17:189–190.

42 Feldman R. IV line placement: a time study for prehospital providers. JEMS 1986; 11:43–45.

43 Pons PT, Moore EE, Cusick JM, *et al.* Prehospital venous access in an urban paramedic system: a prospective on-scene analysis. J Trauma 1998; 28:1460–1463.

44 Spaite DW, Valenzuela TD, Criss EA, *et al.* A prospective in-field comparison of intravenous line placement by urban and nonurban emergency medical personel. Ann Emerg Med 1994; 24:209–214.

45 Tsai A, Kallsen G. Epidemiology of pediatric prehospital care. Ann Emerg Med 1987; 16:248–292.

46 Pepe PE, Copass MK, Joyce TH. Prehospital endotracheal intubation: rationale for training emergency medical personnel. Ann Emerg Med 1985; 14:1085–1092.

47 Smith JP, Boda BI, Hill AS, Frey CF. Prehospital stabilization of critically injured patients: a failed concept. J Trauma 1985; 25:65–70.

48 Minville V, Pianezza A, Asehnoune K, *et al.* Prehospital intravenous line placement assessment in the French emergency system: a prospective study. Eur J Anaes 2006; 23:594–597.

49 Bickell WH, Bruttig SP, Millnamow GA, *et al.* The detrimental effects of intravenous crystalloid after aortotomy in swine. Surgery 1991; 110:529–536.

50 Krausz MM, Bar-Ziv M, Rabinovici R, Gross D. A scoop and run or stabilize hemorrhagic shock with normal saline or small volume hypertonic saline? J Trauma 1992; 33:6–10.

51 Stern SA, Dronen SC, Birer P, Wang X. Effect of blood pressure on hemorrhage volume and survival in a near-fatal hemorrhage model incorporating a vascular injury. Ann Emerg Med 1993; 22:155–163.

52 Gross D, Landau EH, Klin B, Krausz MM. Treatment of uncontrolled hemorrhagic shock with hypertonic saline. Surg Gynec Obstet 1990; 170:106–112.

53 Gross D, Landau EH, Assalia A, Krausz MM. Is hypertonic saline resuscitation safe in 'uncontrolled' hemorrhagic shock? J Trauma 1998; 28:751–756.

54 Gross D, Landau EH, Klin B, Krausz MM. Quantitative measurement of bleeding following hypertonic saline therapy in 'uncontrolled' hemorrhagic shock. J Trauma 1989; 29:79–83.

55 Bickell WH, Bruttig SP, Millanamow GA, *et al.* Use of hypertonic saline/dextran solution versus lactated ringers solution as a resuscitation fluid after uncontrolled aortic hemorrhage in anesthetized swine. Ann Emerg Med 1992; 21:1077–1085.

56 Bickell WH, Wall MJ, Pepe PE. Immediate versus delayed fluid resuscitation for hypotensive patients with penetrating torso injuries. N Engl J Med 1994; 331:1105–1109.

57 Martin RR, Bickell WH, Pepe PE, *et al.* Prospective evaluation of preoperative fluid resuscitation in hypotensive patients with penetrating truncal injury: a preliminary report. J Trauma 1992; 33:354–362.

58 Kwan I, Bunn F, Roberts I. On behalf of the WHO Pre-Hospital Trauma Care Steering Committee. Timing and volume of fluid administration for patients with bleeding. Cochrane Database Syst Rev 2003; (3):CD002245.

59 Bochicchio GV, Ilahi O, Joshi M, *et al.* Endotracheal intubation in the field does not improve outcome in trauma patients who present without an acutely lethal traumatic brain injury. J Trauma 2003; 54:307–311.

60 Murray JA, Demetriades D, Berne TV, *et al.* Prehospital intubation in patients with severe head injury. J Trauma 2000; 49:1065–1070.

61 Stockinger ZT, McSwain NE. Prehospital endotracheal intubation for trauma does not improve survival over bag-valve-mask ventilation. J Trauma 2004; 56:531–536.

62 Eckstein M, Chan L, Schneir A, Palmer R. Effect of prehospital advanced life support on outcomes of major trauma patients. J Trauma 2000; 48:643–648.

63 Gausche M, Lewis RJ, Stratton SJ, *et al.* Effect of out-of-hospital pedictric endotracheal intubation on survival and neurological outcome. JAMA 2000; 283:783–790.

64 Wang HE, Yealy DM. Out-of-hospital endotracheal intubation: where are we?
•• Ann Emerg Med 2006; 47:532–541.
This recent review outlines the controversy regarding prehospital ETI.

65 Bickell WH, Pepe PE, Bailey ML, *et al.* Randomized trial of pneumatic garments in the prehospital management of penetrating abdominal injuries. Ann Emerg Med 1985; 16:653–658.

66 Bodai BI, Walton CB. Mistakes in treatment of accident cases before reaching hospital. Br J Accid Surg 1987; 18:18–20.

67 Trunkey DD. Trauma. Scientific American 1983; 249:28–35.

68 Hoyer CCS, Christensen EF, Andersen NT. On-scene time in advanced trauma life support by anaesthesiologists. Eur J Emerg Med 2006; 13:156–159.

69 Fakhry S, Scanlon JM, Robinson L, *et al.* Prehospital rapid sequence intubation for head trauma: Conditions for a successful program. J Trauma 2006; 60:997–1001.

70 Helm M, Hossfeld B, Schafer S, *et al.* Factors influencing emergency intubation in the prehospital setting - a multicentre study in the German Helicopter Emergency Medical Service. Br J Anaesth 2006; 96: 67–71.

71 Warner KJ, Cuschieri J, Copass MK, *et al.* The impact of prehospital ventilation on outcome after severe head injury. J Trauma 2007; 62:1330–1338.

72 Tracy S, Schinco MA, Griffen MM, *et al.* Urgent airway intervention: does outcome change with personnel performing the procedure? J Trauma 2006; 61:1162–1165.

73 Messick J, Meyer AA. Advanced life support training is associated with decreased trauma death rates: an analysis of 12 417 trauma deaths. J Trauma 1990; 30:1621.

74 Carr Bg, Caplan JM, Pryor JP, Branas CC. A meta-analysis of prehospital care
• times for trauma. Prehosp Emerg Care 2006; 10:198–206.
This is a meta-analysis of studies describing prehospital times. Outcomes are analyzed and compared based on urban, suburban and rural areas.

75 Ornato JP, Racht EM, Fitch JJ, Berry JF. The need for ALS in urban and suburban EMS systems. Ann Emerg Med 1990; 19:1469–1470.

76 Roudsari B, Nathens A, Koepsell T, *et al.* Analysis of clustered data in multicenter trauma studies. Injury 2006; 37:614–621.

77 Roudsari B, Nathens A, Arreola-Risa C, *et al.* Emergency medical service
• (EMS) systems in developed and developing countries. Injury 2007; 38:1001–1013.
This international study outlined the prehospital systems in multiple countries throughout the world.

78 Roudsari B, Nathens A, Cameron P, *et al.* International comparison of
• prehospital trauma care systems. Injury 2007; 38:993–1000.
This international study compared the three major types of EMS systems: BLS, ALS with EMTs as care providers and ALS with physicians as care providers.

79 Sethi D, Kwan I, Kelly AM, Bunn F. On behalf of the WHO Pre-Hospital Trauma Care Steering Committee. Advanced trauma life support training for ambulance crews (Cochrane Review). In: The Cochrane Library. Chichester: John Wiley & Sons Ltd; 2004.