EMS Makes a Difference:

Improved clinical outcomes and downstream healthcare savings

A Position Statement of the
National EMS Advisory Council

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Executive Summary

This paper summarizes the substantial evidence base documenting improved patient outcomes resulting from prehospital interventions and emergency medical services (EMS) systems. It further shows that emergency medical services play an important role within the healthcare system and documents the definitive relationship between EMS-related improvements in patient outcomes and financial savings to the healthcare system. There is a considerable body of evidence documenting the importance of prehospital care in the treatment of ST-segment elevation myocardial infarction (STEMI), stroke, respiratory emergencies, pediatric care and trauma. The literature also suggests that these improvements in patient outcomes are cost effective, and that prehospital care within the context of an EMS system contributes to downstream healthcare savings.

In the context of healthcare reform, the capabilities and potential of EMS and their impact on healthcare costs remain largely unrecognized. EMS can offer quality, systematic primary care in many out-of-hospital settings in coordination with many other healthcare reform efforts. However, in order to realize these benefits and to promote the implementation of evidence-based interventions, economic incentives must be properly aligned. The National EMS Advisory Council (NEMSAC) believes this alignment is necessary to optimize patient outcomes and decrease overall cost in several specific segments of patient call types including, but not limited to: STEMI care, stroke care, trauma care, pediatric care, respiratory care and treat-and-refer without transport of certain patients. The NEMSAC recommends that systems and cost-effectiveness research be conducted along side of these changes to measure the impact.

Introduction

Does EMS make a difference? Do prehospital interventions really improve patient outcomes? Can timely care provided in the prehospital setting lead to reduced total healthcare expenditures? After more than fifty years of prehospital care provided by EMS systems in the United States and associated scientific research, there now exists a sufficient body of scientific evidence to answer this question with an unequivocal YES.

Evidence-based medicine has become the standard for change in healthcare. As healthcare systems become increasingly data-driven, the efficacy and usefulness of Emergency Medical Services (EMS) has come under increased scrutiny. The challenge facing EMS today is to affect a system-wide transformation from practices based on tradition and expert opinion to adoption of national guidelines and protocols that have been developed through a rigorous examination of the scientific evidence and a systematic guideline development process. The growing body of research in prehospital care has reached a critical mass and there now exists a sufficient evidence base to scientifically evaluate the efficacy of select interventions. This paper reviews the literature documenting the efficacy of prehospital care and its resulting impact on patient outcomes and healthcare finance.

The "scoop and run" philosophy of the early years of EMS relied primarily on emergency transport capabilities, and provided minimal medical care. As EMS systems improved, so did the training and education of EMS providers, and certification programs emerged. Although the impact of these certification programs was not rigorously studied at the time of their development, a recent study from Mexico demonstrated a 45% reduction in the severity-adjusted risk of injury death following the implementation of a system-wide training and certification program for prehospital providers in the city of Santa Catarina.[1] During the 6-month implementation phase, certification of prehospital providers increased from 20% to 100%.

Leaders in EMS and healthcare finance experts are both looking for documentation of improved patient outcomes and reduced healthcare system costs resulting from prehospital care and decision making. This document reviews recent studies that have demonstrated positive outcomes from specific conditions including severe trauma, ST-elevation myocardial infarctions, stroke, respiratory distress, sudden cardiac death, and pediatric shock. A common element in all of these findings is the integration of EMS into a coordinated system of prehospital care.[2] If the full potential of EMS is to be realized, additional efforts will be needed to continue research on the outcomes and cost effectiveness of EMS systems of care and translation of these findings into the development and implementation of national evidence-based prehospital and system protocols.

Prehospital Care and Cardiovascular Disease

The strongest evidence demonstrating improved patient outcomes resulting from coordinated systems of prehospital care comes from the treatment of cardiovascular disease symptoms. The American Heart Association (AHA) has promoted the concept of a "chain of survival" for cardiac arrest that describes0 a sequence of events from bystander CPR through EMS interventions and transport to definitive care that are associated with improved survival.[3] The four links in the chain of survival include: rapid access, rapid cardiopulmonary resuscitation (CPR), rapid defibrillation, and rapid advanced life support. A new fifth link is being suggested to include timely post-resuscitative care, primarily hypothermia treatment.[4] By decreasing the time between the onset of symptoms and a patient's arrival to definitive care, and by providing appropriate care in the prehospital setting, EMS personnel, from emergency dispatchers to paramedics, contribute to improved survival from cardiac arrest.

ST-segment Elevation Myocardial Infarction

There are an estimated 500,000 ST-segment elevation myocardial infarction (STEMI) events in the U.S. annually.[5,6] A majority of STEMI deaths occur within 2 hours of the onset of symptoms.[8] For patients with STEMI, time to reperfusion is a key determinant in reducing morbidity and mortality, with percutaneous coronary intervention (PCI) being the preferred reperfusion strategy.[7,21] The treatment goal for patients with STEMI is to provide access to PCI services (aka, door-to-balloon (D2B) time) within 90 minutes of the onset of symptoms.[8] For patients who are treated with PCI, each 30 minutes of delay increases the relative risk of 1-year mortality by 7.5%.[9]

Integrated EMS systems have been shown to play a key role in improving STEMI outcomes. The EMS interventions that have been demonstrated to contribute most significantly to improved outcomes are those that result in earlier diagnosis and more timely reperfusion, specifically the capture and interpretation of 12-lead ECGs, notification of the receiving hospital and activation of coronary care or catheter lab teams, triage directly to a PCI center, and administration of thrombolytic agents during transport. The evidence base for these interventions is reviewed below.

Although early efforts to identify STEMI patients in the field relied on clinical checklists and/or direct physician consultation, the current standard of care is the acquisition and interpretation of a 12-lead ECG. Based on a substantial body of evidence, the American Heart Association (AHA) [10,11,12] and others[13,14] strongly encourage the use of 12-lead ECGs by paramedics to evaluate all adult patients with non-traumatic chest discomfort recommend that confirmed STEMI patients be transported to PCI-capable facility,[8] even if it means bypassing a closer hospital.

In spite of the AHA recommendations, less than 10% of EMS providers nationwide use ECGs in STEMI patients, a rate that has remained unchanged for the last decade.[2,3] Even in systems that have acquired prehospital ECG capabilities, their use is not always coordinated with the hospital system to improve the timeline for reperfusion therapy.[3] Use of 12-lead ECGs is more common in larger urban EMS systems where a recent survey of EMS systems serving the 200 largest US

cities indicated that 84% of these urban EMS systems reported having 12-lead ECGs "available."[15]

Several studies have documented the abilities of paramedics to acquire and accurately interpret 12-lead ECGs in the field.[16,17,18,19,20,21, 22,23,24] Le May and colleagues demonstrated that advanced care paramedics (ACPs) could be trained to accurately interpret prehospital electrocardiograms (ECGs) for the detection of ST-segment elevation myocardial infarction in the field.[23] Similarly, van't Hof and colleagues found that paramedics in the Netherlands were able to diagnose STEMI in the ambulance and triage patients to a PCI center without need to consult with a physician. [24] In that study, field diagnosis and triage directly to a PCI center was found to be feasible in 95% of STEMI patients and was associated with improved left ventricular function and better clinical outcomes. Provo and Frascone studied whether the ability to successfully acquire and transmit ECGs could be taught to Basic Life Support personnel (EMTs) and concluded that the practice was feasible, but that it increased scene times by approximately 5 minutes. Utilizing this capability, particularly in tiered EMS systems or systems operating without paramedic personnel has significant potential to improve D2B times, especially in rural areas. [25]

Prehospital identification of patients experiencing STEMI has been shown to be an important factor in significantly improved outcomes through clinically relevant reductions in door-to-balloon (D2B) times.[26,8] This was demonstrated in the Ottawa, Ontario, EMS system, where D2B time decreased from an average of 123 minutes when diagnosed at a non-PCI hospital to 69 minutes when diagnosed in the prehospital setting and transported directly to a PCI-capable facility, a reduction of 44%.[22,23] A D2B time of less than 90 minutes was achieved for 79.7% of patients who were triaged by paramedics and transported directly to a PCI-capable facility compared to 11.9% of patients transferred from emergency departments ($p < 0.001$).[22] Similarly, in a series of 233 consecutive STEMI patients treated in more rural Medford, Oregon, D2B times of 90 minutes or lower were achieved in 58.3% of patients diagnosed by paramedics and transported directly to a PCI hospital, compared with only 5.2% of patients transferred from a referring hospital emergency department ($p < 0.001$). In-hospital mortality was 0% in paramedic identified patients versus 4.3% for those transferred from a referring hospital ($p = 0.007$).[27]

The success of field identification of STEMI patients followed by direct transport to a PCI center, bypassing non-PCI capable hospitals has been demonstrated in an urban Canadian EMS system, where median door-to-balloon times for STEMI patients who received field ECGs and were transported directly to a PCI center were 54 minutes lower than D2B times for patients who received ECGs in the emergency department.[22] Similarly, in Germany, this practice decreased D2B times from 54 minutes to 26 minutes (52% reduction) and reduced first medical contact to balloon time from 113 to 74 minutes (35% reduction).[3] A study from Newark, NJ, had using historical controls reported D2B times at 146 minutes for STEMI patients who received ECGs at referring hospitals versus 80 minutes when the diagnostic prehospital ECGs was administered in the field.[12] Even in a rural NC EMS systems that did not have access to 12-lead ECGs, early identification of potential STEMI patients using a symptom checklist followed by direct transport to a PCI center resulted in a decrease in mean D2B time from 101 minutes to 50 minutes.[12]

The prehospital administration of thrombolytic agents may be appropriate in rural areas where transport times to the nearest PCI center are more than 90 minutes. In Uppsala Sweden, Bjorklund and colleagues found that the median time from symptom onset to the administration of thrombolytic treatment was 113 minutes for pre-hospital administration and 165 minutes for in-hospital thrombolysis. One-year mortality for these patients was decreased 40% for those receiving prehospital treatment (7.2% versus 11.8% for in-hospital thrombolysis), after adjusting for baseline characteristics (OR = 0.71, 95% CI = 0.55, 0.92; p = 0.008).[28]

Research shows an approximate 10 minute decrease in door to drug time and 15-20 minute decrease in door-to-balloon time for patient using the EMS system compared to patients arriving to the ED on their own.3 These times do not reflect the further time reduction for activating the catheter lab while still en route to the hospital, which is quickly becoming a standard of care for EMS systems that coordinate with accredited Chest Pain Centers.

In spite of the proven effectiveness of prehospital interventions for STEMI, only 24% to 44% of all STEMI patients use the EMS system when they experience symptoms.[8,29]. Moyer states, "This poses a special challenge to ED personnel, because STEMI patients arriving by ambulance typically receive attention and treatment faster than patients who transport themselves". For STEMI patients arriving in ED with no PCI labs, ambulance transport to PCI-capable facilities should be considered a "911" call rather than a "next-available" ambulance criteria to minimize time in the ED.[8] There is a tremendous opportunity to improve patient outcomes through educating the public to activate the EMS system at the first sign of a heart attack.

Automatic External Defibrillation

The American College of Cardiology (ACC)/AHA STEMI guidelines recommend that 9-1-1 emergency dispatchers ask patients with symptoms suggestive of an acute STEMI to take an aspirin (unless allergic) and provide instruction in bystander CPR while first-responder and ambulance units are on the way.[30,31] Public safety first responders, who ideally arrive within five minutes of the call, can provide first aid, oxygen, CPR, and often early defibrillation through the use of automated external defibrillators (AEDs).[2]

Defibrillation immediately after witnessed cardiac arrest results in survival rates as high as 90%.[32] Each minute that the heart remains in fibrillation results in a decrease in survival of approximately 10%.[33, 36,37,38] The use of AEDs by lay persons,[34,35] first responders,[36,37,38] EMTs, and paramedics[39,40,41] has been found to reduce time to defibrillation and improve survival and neurologic outcomes from sudden cardiac arrest.

Response times and cardiac arrest survival rates for patients defibrillated by first responders (police and fire fighters) have been shown, in some communities, to be better than patients defibrillated by EMTs or paramedics.[36,37,42,43,44] However, the overall contribution of defibrillation to survival from sudden cardiac arrest depends upon the efficiency of the chain of survival of the overall EMS system.[45] The addition of first responder defibrillation to an EMS system with either very fast response times[46,47] or with prolonged transport times to definitive care[48] has not been demonstrated to improve survival rates.

EMS has long focused its response on cardiac arrest scenarios. Most response time standards across the country are developed to reach a cardiac arrest victim in a timely manner and improve the chances for survival. Unfortunately, cardiac arrest survivability varies considerably across the country. The two primary factors affecting survival from out-of-hospital cardiac arrest are the time from initial collapse to CPR and the time to defibrillation. When both are delivered rapidly, survival rates and neurological outcomes improve and can approach 50 percent for patients in ventricular fibrillation.[4]

A study conducted in Italy evaluated cardiac arrest survivability with no neurological deficits by adding AEDs to the all volunteer EMS system in place of the manual defibrillators being used on a few of their ambulances and in the hospital Emergency Departments. Survival increased from 0.9 percent to 3 percent keeping all other procedures the same. An increase in survival was noted in both urban and rural areas, although the increase was significantly higher in urban areas. Improved survival was also positively correlated with shorter total response time and a larger number of deployed devices per population density."[49]

Stroke

Stroke is the third leading cause of death in the United States. Each year, approximately 795,000 persons suffer a first time or recurrent stroke, with a mortality rate of approximately 18%.[50] The Centers for Disease Control and Prevention (CDC) report that in 1999 approximately 48% of stroke deaths occurred before transport to a hospital emergency department, although pretransport death rates vary considerably between States, ranging from 23% to more than 60%.[51]

Intravenous infusion of thrombolytics remains the best treatment for acute stroke management[52] and is associated with reductions in mortality and in severe disability.[53,54, 55] Aggressive management protocols suggest a therapeutic window for effective reperfusion of ischemic brain tissue of approximately 3 hours,[56] however, currently only between one-half to three-quarters of stroke patients arrive at a hospital within this treatment window.[57,58,59] Decisions made by EMS personnel can affect treatment and contribute to the immediate, short-term, and long-term outcomes of stroke patients.[60]

The American Stroke Association has identified a “Stroke Chain of Survival” which consists of four components: rapid recognition of stroke warning signs and immediate use of the 9-1-1 system, rapid EMS assessment; priority transport with prenotification of the receiving hospital; and rapid and accurate diagnosis and treatment at the hospital.[61] The reasons most frequently cited for not receiving thrombolytic treatment relate to breakdowns in components of the survival chain, namely delays in calling 9-1-1, transporting patients to a hospital capable of handling stroke patients, and diagnosing and treating patients after they arrive at the hospital. [62]

In order to improve stroke outcomes, the National Association of EMS Physicians recommends that EMS personnel should be skilled in the performance of prehospital stroke screening and should communicate with receiving facilities as soon as possible and that EMS medical directors should develop local/regional strategies for treating, triaging, and transporting patients with acute stroke symptoms.[63] Several instruments are available to assist with the prehospital screening and identification of acute stroke, for emergency medical dispatchers and paramedics, with

varying results. [64,65, 66,67,68] The Ontario prehospital stroke screening tool, used by paramedics, has been shown to have a positive predictive value of 89.5% (95% CI: 85.7, 92.7).[64] Another study of prehospital identification of acute stroke found that paramedics using the Cincinnati Prehospital Stroke Scale and emergency medical dispatchers using a Medical Priority Dispatch System protocol and have been shown to identify stroke patients with a positive predictive value of 40-45% and sensitivity of between 44-83%, respectively.[65] In Houston, Texas, the accuracy of paramedic diagnosis of stroke was increased from 61% to 79% through educational intervention.[69]

The Northeast Cerebrovascular Consortium has documented significant disparities in the delivery of stroke care and associated differences in patient outcomes across an 8-State region, these differences were especially pronounced when comparing urban and rural areas.[70] A study of stroke knowledge and practice among frontier and urban EMS providers in Montana found no difference in the providers' ability to correctly identify stroke risk factors or warning signs, but indicated that providers from frontier areas were less likely to have a stroke protocol in place than their urban counterparts (58% vs. 66%).[71] Following a comprehensive review of the literature, Leira, et al., concluded that the gap in rural-urban stroke management practices can be overcome with a comprehensive program of education of rural caregivers, remote support from tertiary care institutions, as well as continued clinical trials.[72]

While many EMS systems have both STEMI and stroke protocols in place, Brice, et al., found that in a survey of 83 primary EMS agencies in North Carolina, fewer agencies provided stroke education to EMS personnel than cardiac arrest, during a recent two-year period (86% vs. 96%) and that the median training time devoted to stroke was one-half that for chest pain (6 vs. 12 hours).[73]

There is a growing body of evidence documenting of the specific contribution of EMS systems to shorter times to thrombolysis and improved stroke outcomes. The feasibility and effectiveness of an emergency clinical pathway using EMS to provide advanced notification to hospitals of the arrival of potential stroke patients has been demonstrated in a cluster randomized trial in the Latium region of Italy. A prospective cohort study using historical controls in New South Wales, Australia, found that implementation of a protocol comprising a prehospital stroke assessment tool, an ambulance protocol for hospital bypass for potentially thrombolysis-eligible patients, and prehospital notification of the acute stroke team resulted in an increase of patients receiving tissue plasminogen activator (tPA) from 4.7% to 21% ($p < 0.001$); a 40% reduction in median times from symptom onset to ED arrival ($p = 0.004$); and a 35% reduction in time from ED arrival to stroke unit admission ($p = 0.001$). Of those patients treated with tPA, 43% had minimal or no disability at 3 months.[74]

De Lucca and colleagues found that stroke patients transported by specially trained EMS personnel who provided advanced notification to the receiving hospital were nearly twice as likely to be referred to a specialized stroke unit (24% vs. 13%), and more than four times more likely to receive thrombolysis (8.6% vs. 1.7%) than patients arriving via non-trained EMS providers. In Toronto, Canada, a citywide prehospital acute stroke activation protocol to transport acute stroke directly to one of 3 regional stroke centers, bypassing local hospitals, was implemented by the provincial government. The protocol resulted in an immediate doubling in the number of patients with acute stroke arriving to the regional stroke centers within 2.5 hours

of symptom onset and increased the tissue plasminogen activator treatment rate from 9.5% to 23.4%. A third study of advanced notification of receiving facilities by EMS providers yielded a 17% decrease in time to computed tomography (CT) and a nearly two-fold increase in the percentage of patients receiving thrombolysis.[75,76]

Delays in calling 9-1-1 by patients who are experiencing symptoms was found to be the single most important component in failure to provide thrombolytic treatment within the 3-hour window.[77] The CDC has called for more extensive public education on the early recognition of stroke and the urgency of telephoning 9-1-1 to receive ambulance transport.[56] A recent pilot study in West Virginia suggests that the public's knowledge of stroke signs and symptoms was increased using communitywide EMS-based community awareness campaign, suggesting another avenue whereby EMS providers can positively impact stroke outcomes.[78]

The American Stroke Association (ASA) has recently called for an establishment of stroke systems of care and identified the activation and response of EMS as one of the seven critical components of effective stroke systems of care.[79] Specifically, the ASA's 2004 Task Force recommended four areas of EMS action to improve stroke outcomes: (1) activate and dispatch EMS response for stroke patients; (2)use of protocols, tools, and training; (3) develop training, assessment, treatment, and transportation protocols for stroke; and (4) transport to the nearest stroke center if the center is located within a reasonable transport distance and time.[79]

Respiratory Care

Respiratory distress is the second most common complaint of EMS patients and has a high mortality rate of 18% before hospital discharge. More than 2 million patients are transported in the US each year for respiratory distress.[80] Common causes include asthma, chronic obstructive pulmonary disease, pneumonia, and congestive heart failure.[81]

The Ontario Prehospital Advanced Life Support (OPALS) Study was a controlled multi-phased before/after study conducted in 15 Canadian cities that assessed outcomes from respiratory distress during a 6-month BLS response phase followed by a 6-month ALS response phase. The authors found that mortality decreased significantly, from 14.3% to 12.4% ($p = 0.01$). The proportion of survivors with the higher-functioning cerebral-performance scores at discharge also increased significantly, from 52.3% to 62.5%, ($p < 0.001$) for patients receiving ALS treatment. In addition, the rate of intubation in the emergency department decreased from the basic-life-support phase to the advanced-life-support phase (from 5.3% to 3.1%, $p < 0.001$). The OPALS Respiratory Distress Study showed that the introduction of an EMS advanced-life-support program and interventions for symptom relief significantly reduced mortality for patients with shortness of breath.[81]

Cardiogenic Pulmonary Edema

Cardiogenic pulmonary edema (CPE) is a common presentation in the prehospital setting that traditionally has been treated with supplemental oxygen, vasodilators, and, in more severe cases, endotracheal intubation. Continuous positive airway pressure (CPAP) has demonstrated to be an

effective treatment when administered in hospitals[82] and has been suggested for more widespread use in the prehospital setting.[83]

Plaisance and colleagues undertook a randomized trial of the benefit of CPAP in the treatment of CPE in the prehospital environment. Patients with CPE were randomly assigned to treatment groups comprising either early CPAP, late CPAP or no CPAP given with or without standard medical treatment. When compared to usual medical care, the immediate application of CPAP alone in the pre-hospital treatment of acute congestive pulmonary edema resulted in significantly improved admission physiology, a reduction of symptoms, and significantly reduced rates of endotracheal intubation and in-hospital mortality.[84]

The introduction of continuous positive airway pressure (CPAP) into the pre-hospital environment has reduced the need to intubate these patients with acute pulmonary edema in the field or in transport. The evidence for the advantage of non-invasive ventilation techniques, and especially of CPAP, over standard medical treatment is now robust, and its use as a first line intervention in acute pulmonary edema patients is becoming mandatory.[85] CPAP not only reduces the need to intubate but produces better clinical results in the on-going care of patients in the absence of serious side effects.

Regionalized Systems of Care: Trauma and Pediatric Shock

The establishment of tertiary care hospitals with specialties such as PCI, stroke, trauma, and shock facilitates the delivery of high-quality emergency care. There is substantial evidence that the use of regionalization of services to direct patients to specialty care centers improves outcomes and reduces costs across a range of high-risk conditions and procedures.[86] The success of regionalization, however, depends on well-functioning EMS systems to deliver patients to tertiary care centers.

Severe Trauma and Traumatic Brain Injury

An estimated 500,000 adult patients are transported to hospitals after experiencing major trauma in the United States each year.[87] Stiell, et al., describe major trauma as "life-or limb-threatening injury due to blunt force, penetrating injury or burn injury."[87] Considering frequency and associated mortality, major trauma, is the second most important condition for children and the fourth most important condition for adults treated by emergency medical service providers. About 20% of these patients die, and many survivors are left with permanent disability.[87] The total cost of injury in the United States in 1995 was estimated at $260 billion; injury and its consequences accounted for 12 percent of all medical spending.[88]

Much of the impetus behind the development of modern EMS systems can be traced to national efforts to reduce death and disability from highway crashes in the 1960s. Passage of the Highway Safety Act of 1966 directed the NTHSA to improve EMS systems across the nation. Since that time EMS systems have proven critical in quickly delivering traumatically injured patients to definitive care. An important part of an EMS system is a regionalized trauma care system, defined in the Trauma System Agenda for the Future as, "an organized, coordinated effort in a defined geographic area that delivers the full range of care to all injured patients and is integrated with the local public health system."[89] The Agenda states that the true value of a

trauma system is derived from the seamless transition between each phase of care, integrating existing resources to achieve improved patient outcomes.

Mackenzie, et al., examined differences in mortality for adult patients treated in 18 hospitals with a Level I trauma centers compared to trauma patients treated at 51 hospitals without a trauma center in a 14-State region. After adjusting for differences in injury severity and patient demographics, the authors found that the risk of death was 25% lower when care was provided in a trauma center, compared to a non-trauma center.[90] Relative differences in risk, however, varied according to injury severity, with the greatest difference in mortality risk seen for patients with the most severe injuries.

System-wide implementation of an evidence-based prehospital treatment protocol for patients with traumatic brain injury (TBI) [91] has been shown to decrease mortality by 50% compared to historical controls (17.0% vs. 36.4%; $p < 0.04$); among surviving patients, maximum scores on tests of neurological function at 14 days post injury, were achieved by 66.0% of the patients treated according to the protocol versus 36.4% of the historical controls.[92] The key guideline components focused on airway management, blood pressure support, and transport. During the study period scores on tests given immediately before and after training, and at 3 months after training demonstrated significant gains and retention of knowledge relating to the care of patients with traumatic brain injury by field providers. These results are supported by European studies that have shown improved survival and neurological outcome for severe TBI for patients who received aggressive fluid resuscitation and helicopter transport. [93,94]

EMS systems including trauma centers have been shown to be especially beneficial for severely injured patients,[90] those with traumatic brain injury,[92] vascular injuries,[95] and younger patients (Haas). [96] Subsequent analysis of the data reported by MacKenzie revealed that differences in survival were not the result of more rapid assessment and intervention alone, emphasizing the complex factors that contribute to improved survival.[96] In a study of 1019 patients with penetrating abdominal injury or multisystem blunt trauma treated at Level I and Level II trauma centers, Nathens, et al., found that trauma centers treating 650 or more trauma patients annually had improved rates of survival for patients with penetrating abdominal injury arriving in shock and for comatose patients with multisystem blunt trauma. In addition to improved survival rates, the authors found that patients treated at the high-volume centers had significantly shorter length of stay in hospital, after adjusting for injury severity; patients with abdominal injury stayed an average of 1.6 fewer days and patients with multisystem trauma stayed an average of 3.3 fewer days than those treated at the lower-volume centers.[97]

In order to realize the maximal benefit of trauma center care, EMS personnel must accurately determine which patients require triage to a tertiary center. The current revision of the American College of Surgeons' (ACS) Field Triage Decision Scheme uses a 4-step process to determine the most appropriate destination facility within the local trauma care system.[98] Using an earlier version of the ACS Guidelines, Norcross and colleagues report that EMS personnel can make appropriate triage decisions in the field.[99]

While there is strong evidence supporting the effectiveness of trauma centers and trauma systems, research on some specific prehospital treatments has failed to demonstrate the efficacy of these interventions. The OPALS Trauma study sought to determine whether prehospital

Advanced Life Support (ALS) programs provided a patient benefit on trauma-related mortality and morbidity compared to Basic Life Support (BLS) programs. In this controlled clinical study, the authors found that the system wide implementation of prehospital advanced life-support did not decrease mortality or morbidity among major trauma victims. Despite the large sample, controlled design and multiple approaches to the analysis, Stiell and colleagues found no evidence of benefit in any clinically relevant subgroup of patients. To the contrary, the evidence suggested that patients with Glasgow Coma Scale scores less than 9 had worse survival during the advanced life-support phase than during the basic life-support phase. The findings support the contention that definitive trauma care is best provided in the operating room and that prehospital interventions may be associated with increased complications or may delay transfer to a hospital. The authors therefore concluded that emergency medical services should carefully re-evaluate the indications for and application of prehospital advanced life-support measures for patients with major trauma.[81]

Pediatric Shock

Most of the studies of trauma center and EMS system effectiveness have excluded children. Much of the presumed evidence base for the prehospital care of children is inferred based on findings of effectiveness in the emergency department or other healthcare settings, although intervention efficacy in the field settings can be compromised.[100] Notwithstanding this fact, the field application of the Pediatric Advanced Life Support (PALS) or Advanced Pediatric Life Support (APLS) guidelines shows promise toward improving outcomes of children experiencing symptoms of shock.[101] Current clinical practice guidelines for hemodynamic support of pediatric shock recommend first hour fluid resuscitation and inotrope therapy to restore normal blood pressure.[102] Analysis of children receiving treatment for septic shock in a pediatric intensive care unit indicated that children receiving less than a 20-mL/kg dose of resuscitation fluid in the first hour of treatment experienced a mortality rate of 73%, whereas children who received more than a 40-mL/kg dose in the first hour or treatment had a mortality rate of 33% ($p < 0.05$), a reduction of more than 50%.[103]

The PALS guidelines reduce mortality and improve functional outcomes when used by physicians in both emergency departments[101] and community hospitals.[104] Carcillo, et al., found that if emergency department physicians recognized shock in pediatric patients, as determined by heart rate, capillary refill time, and systolic blood pressure – the same parameters used by EMS personnel – and used PALS/APLES treatment guidelines, early shock could be reversed with good health outcomes. Early reversal of shock in non-trauma patients was associated with significant reductions in mortality (OR 0.31; 95% CI 0.20, 0.48) and functional morbidity (OR 0.20; 95% CI 0.07 – 0.57). Trauma patients had a marked reduction in mortality (OR 0.07; 95% CI 0.01 – 0.33), but not functional morbidity with early shock reversal.[101]

Recognition of shock and timeliness of care are paramount in improving pediatric health outcomes, especially in community hospital settings. In a single-center study, Carcillo and colleagues found that that time-sensitive use of American College of Critical Care Medicine/PALS guidelines for the resuscitation of pediatric and newborn septic shock was associated with a four-fold reduction in mortality. Each hour that progressed without implementation of these guidelines was associated with a 40% increased risk of mortality. Early

treatment following PALS/APLS guidelines in the community hospital/emergency department appeared to prevent functional morbidity in these children. [104]

Based on these findings, the authors recommend a systems approach for all pediatric shock patients, stating that once shock is identified by emergency medicine technicians, triage nurses, and emergency medicine physicians, there is little reason not to provide the same organized systems approach to the non-trauma patient as is provided to the trauma patient because both benefit from timely resuscitation. The success of PALS training for EMS personnel in improving pediatric resuscitation skills suggest that the success of hospital-based interventions for pediatric shock may extend to the prehospital setting. In a study of children transported to a tertiary children's hospital/pediatric trauma center, a retrospective review of prehospital care by physicians who were blinded to the training status of EMS personnel indicated that those with PALS training demonstrated significantly higher rates of vascular access in cases of shock/arrest (100% vs. 70%; $p > 0.001$) and in intraosseous line placement (100% vs. 55%; $p < 0.01$).[105] To be effective at the system level, EMS personnel must be trained to recognize early signs of shock in children and to follow the PALS/APLS guidelines.

Pediatric emergency care should be considered a system of care similar to STEMI, stroke, and trauma programs. To this end, the Health Resources and Services Administration (HRSA) has implemented Performance Measure 66c requiring all state and territorial EMS for Children grantee programs to report progress on the existence of a statewide, territorial or regional standardized system that recognizes hospitals that are able to stabilize and/or manage pediatric medical emergencies and trauma.[106]

Expanded Services and Interventions that Improve System Efficiency

The *EMS Agenda for the Future* describes a vision of an expanded role for EMS in which EMS providers and first responders will be more integrated with preventive services and acute care and will be more focused on promoting overall community health.[107] This will facilitate faster access, improved pre-hospital care, and more seamless patient care throughout the continuum of care. Critical Access Hospitals will be better integrated with EMS systems. EMS will continue to serve as the community's safety net and will be funded more reliably and appropriately for service to the community. Unfortunately, subsequent reductions in funding for EMS systems have significantly curtailed full implementation of the vision.

The clinical scope of practice of emergency medical responders, technicians and paramedics has evolved, as the profession has matured. Increasingly, providers are being entrusted with more advanced capabilities. Basic EMTs are now able to perform skills reserved only for paramedics in years past and paramedics have been entrusted to perform more advanced techniques, use additional tools, and use more clinical judgment in their decision making. [108]

The evolving role of EMS has great potential in the broader field of medicine. With increased demand for services and skyrocketing healthcare costs, alternative models of service delivery can provide added value to the healthcare system. Several studies have documented the feasibility and efficacy of expanded scopes of practice.

Hypoglycemia

In addition to improving survival from specific conditions, prehospital care has been shown to make a difference in non-survival outcomes relating to healthcare system efficiency. Several authors have studied the feasibility and outcomes of allowing BLS providers to perform glucometry for patients experiencing hypoglycemic events (currently, rapid glucose testing is within the recommended scope of practice for paramedics, but not for BLS providers in the United States).[108] In King County, Washington, BLS providers, who were trained in glucometry, used test results to guide decisions regarding the need to request paramedic evaluation of patients experiencing hypoglycemic events. A review of the first 500 consecutive uses of glucometry by King Co. BLS providers showed that the test results prompted EMTs to upgrade the triage level and request paramedic evaluation for 5% of patients; caused them to downgrade the triage level, canceling already dispatched paramedics for 5% of patients; and allowed EMTs to function without paramedics when they otherwise would have called for assistance for 11% of patients.[109] Similar results were observed in a different EMS system where the combination of pulse oximetry and glucometry by BLS providers was found to yield significant improvements in system efficiency with respect to paramedic involvement.[110]

Prehospital treatment of hypoglycemia without transport to a hospital emergency department may also result in improved system efficiency and patient satisfaction without compromising patient outcomes. Exploratory studies have examined rates of rehospitalization for patients treated for hypoglycemia in the field and found no significant differences in hospital admission during the subsequent 48-hours or intervals between hypoglycemic episodes compared to patients who were transported to a hospital.[111, 112]

.*Geriatric Care*

In the UK, the Ministry of Health has been encouraging the use of non-physician staff to perform some types of medical care typically reserved for physicians. For example, in South Yorkshire, England, elderly patients were identified as making 12% to 21% of all visits to emergency departments and having the greatest potential to benefit from a care provided by a paramedic with an expanded scope of practice. Local paramedics received a three-week fulltime theory-based course on care of the elderly and subsequently underwent a 45-day supervised practice clinical rotation prior to providing in-home care to elderly patients. In a clustered randomized controlled trial, Mason and colleagues assigned elderly patients with specific conditions to either care by the specially trained paramedic practitioners or customary ambulance response.[113] Patients treated by the paramedic practitioners were less likely to be treated in an emergency department either during the initial episode or in the next 28 days (62.6% v 87.5%; $p < 0.001$), and were also less likely to have required hospital admission (40.4% v 46.5%, $p < 0.001$). Elderly patients in the intervention group were more likely to report being “very satisfied” with the care they received than those in the control group (85.5% v 73.8%, $p < 0.001$). The authors concluded paramedics with extended skills working in the community can provide a clinically effective alternative to standard ambulance transfer and treatment in an emergency department for elderly patients with acute minor conditions.[113]

Asthma

The ability of Basic EMTs to safely administer nebulized albuterol to acute asthma patients in the out-of-hospital setting has been demonstrated.[114,115] In a prospective, observational cohort study, nebulized albuterol was administered to 60% of the 3,351 patients aged 1-65 years who called 9-1-1 with asthma-related complaints. Following albuterol administration, peak expiratory flow rates increased by 14.4% (95% CI = 13.8, 15.1), other clinical outcome measures, including dyspnea index, respiratory rate, and use of accessory muscles, also showed improvement.[115]

Minor Complaints

In Minnesota, researchers demonstrated that Basic EMTs could accurately identify wounds repairable in the field and wounds requiring tetanus prophylaxis.[116] In this EMS system, identification of wounds that could be repaired in the field would eliminate the need for ambulance transport and an emergency department visit, potentially reducing emergency department crowding and patient waiting times. Another approach to improving the utilization of ED resources was demonstrated in King County, WA, where EMS providers effectively triaged patients with minor complaints to an urgent care clinic rather than the local emergency department. The authors report that patients receiving care in the ED decreased from 51.8 percent to 44.6 percent during the study period, care provided in the clinic went up to 8.0 percent from 4.5 percent, and non-transports increased to 47.4 percent from 43.7 percent. The authors conclude that based on physician review and patient interviews, the alternate care intervention appeared to be both safe and satisfactory. [117]

On-scene Termination of Resuscitation

Identifying patients in the prehospital setting who have no realistic hope of surviving an out-of-hospital cardiac arrest has been proposed as a way to enhance utilization of scarce healthcare resources by reducing the total number of transports and thereby improving the availability of system resources for other uses.[118] Clinical prediction rules for BLS and ALS providers have demonstrated high levels of specificity in correctly identifying in the field patients who were not successfully resuscitated in hospital emergency departments.[119],[120]

Studies of clinical prediction rules have shown high levels of specificity and demonstrated significant prospective savings to EMS systems by not transporting to hospitals only patients with realistic possibilities of resuscitation.[121, 122] In a series of 1240 consecutive patients with out-of-hospital cardiac arrest, Morrison, et al., determined that implementation of these rules would have resulted in a decrease in the rate of transportation from 100 percent to 37.4 percent, and significant savings to the EMS system.[121] A reduction by more than 70% of the nearly 100,000 out-of-hospital cardiac arrests transported annually in the United States[123] could significantly decrease resuscitation-related healthcare expenditures and improve EMS system resource availability for other emergencies. However focus groups comprising field providers, nurses and emergency physicians have identified several potential barriers to widespread termination of resuscitation protocols, including third-party payor incentives for transport, State legislative mandates for transport, and perceived community expectations.[124]

EMS Systems: Performance and Cost

In spite of the frequency with which the public calls upon EMS as its point of entry into the healthcare system, the costs of providing out-of-hospital care and cost-effectiveness of EMS systems and interventions are not well documented, nor is local EMS system performance routinely monitored in many areas of the country.

EMS System Performance Measures and Data Collection

Clearly defined performance measures and uniform data systems are key components of evaluating the efficacy of any system. Unfortunately, EMS performance measures have not been widely used until relatively recently. Many EMS systems in the US do not track patient outcomes, making performance difficult to measure.[88]

Traditionally, EMS system performance has been evaluated primarily based on response times and cardiac arrest survivability. While both measures are important, neither fully defines the quality of care provided by an EMS system or provides comprehensive information on patient outcomes. Response times often do not reflect patient outcomes and cardiac arrest patients represent only a small fraction of the total EMS calls.[125] Cardiac arrest patients are also highly variable and in many cases, survivability is beyond the control of the EMS providers due to delays in EMS system activation. Recent advances in EMS data collection and the development of national EMS performance measures now provide the building blocks for a higher level of monitoring EMS system performance.

The National EMS Information System (NEMSIS) was created to standardize the collection of prehospital data. The three primary goals of NEMSIS are (1) implement an electronic EMS documentation system in every local EMS system, (2) implement a state EMS information system in every state and territory, and (3) implement a national EMS database. There are currently 23 states submitting NEMSIS compliant data to the national database and all states and territories have signed memoranda of understanding signaling their commitment to become NEMSIS compliant.

A considerable effort is underway to expand performance measures beyond response time performance and cardiac arrest survivability. The EMS Performance Measure Project co-sponsored by the National Association of State Officials and the National Association of EMS Physicians has identified 35 performance measures to better gauge EMS administration and operations and develops a better picture of EMS capabilities nationwide.[126] In 2007, the U.S. Metropolitan Municipalities' EMS Medical Directors' Consortium developed a model to encompass a broader range of clinical situations, including myocardial infarction, pulmonary edema, bronchospasm, status epilepticus, and trauma. The consortium hopes this model will improve EMS system design and deployment strategies while enhancing the benchmarking and sharing of best practices among EMS systems.[125]

These efforts to develop more comprehensive performance measures indicate a desire within the EMS community to better identify and define the impact the EMS system has on patient care and

demonstrate that no one factor defines the quality or the capability of EMS. A combination of measures will more accurately portray the current state of EMS systems and help identify proficiencies and deficiencies in the nation's EMS systems.

The Cost of EMS

The clinical research evaluating EMS outcomes clearly demonstrates that EMS systems and treatments make a significant difference for many clinical conditions. For many conditions, the greatest benefit occurs when EMS systems are fully integrated into the larger healthcare system. The importance of this integrated approach to prehospital care is seen most dramatically in trauma care, STEMI programs and stroke systems, resulting in clearly improved patient outcomes. In many cases, emergency medical services are the point of entry into these specialized, integrated healthcare systems. These high-performing EMS systems improve patient outcomes and can decrease the need for future, more extensive care.

According to David R. Miller, "the future of EMS is indivisibly linked to how it is funded. In order to optimize the positive influence of EMS on community health, we must move to a system of finance that is proactive, accounting for the costs of emergency safety net preparedness and aligning EMS financial incentives with the remainder of the health care system."[107] Because EMS operates at the intersection of healthcare, public health and public safety (See Figure 1.) local EMS systems are often not fully fiscally integrated into any of these sectors, and therefore they typically receive inadequate financial support from each of them.[86]

In order for EMS systems and the communities they serve to determine which prehospital interventions and protocols to use, decision makers must know about the costs and cost-effectiveness of interventions as well as the efficacy of the interventions. However, information on the cost of EMS systems and interventions is limited. Lerner and colleagues conducted a structured review of this literature published from 1966 to 2003. Out of 3,533 potentially relevant citations identified through a MEDLINE search, only 32 met the review inclusion criteria. The articles reviewed primarily focused on the costs relating to prehospital treatment of cardiac arrest (41%) and trauma (25%). Of the 32 articles selected for review, only two studies met all the authors' criteria for a high-quality economic evaluation and 2 studies met none of the criteria.[127]

A Standardized Financial Model

As healthcare costs have continued to increase, the cost-effectiveness of EMS interventions has come under scrutiny.[128,129,130] Rigorous cost analyses of EMS systems and interventions should follow guidelines such as those recommended by the Panel on Cost-Effectiveness in Health and Medicine[131] and should utilize a conceptual framework specific to EMS, such as that developed by Lerner, et al.[132] In this model, the authors identified ten components of an EMS cost framework: Human Resources, Physical Plant, Vehicles, Equipment, Communication, Medical Oversight, Administrative Overhead, Training, Information System, and Bystander Response to Medical Emergencies. Use of such this conceptual framework allows for meaningful comparisons to be made across EMS systems and across studies. Lerner, et al., approached the framework from a societal perspective, which includes downstream healthcare costs, as well as

costs incurred by society. The analysis is not limited to single agencies, but all costs associated with EMS, including other sectors as she displayed.[132]

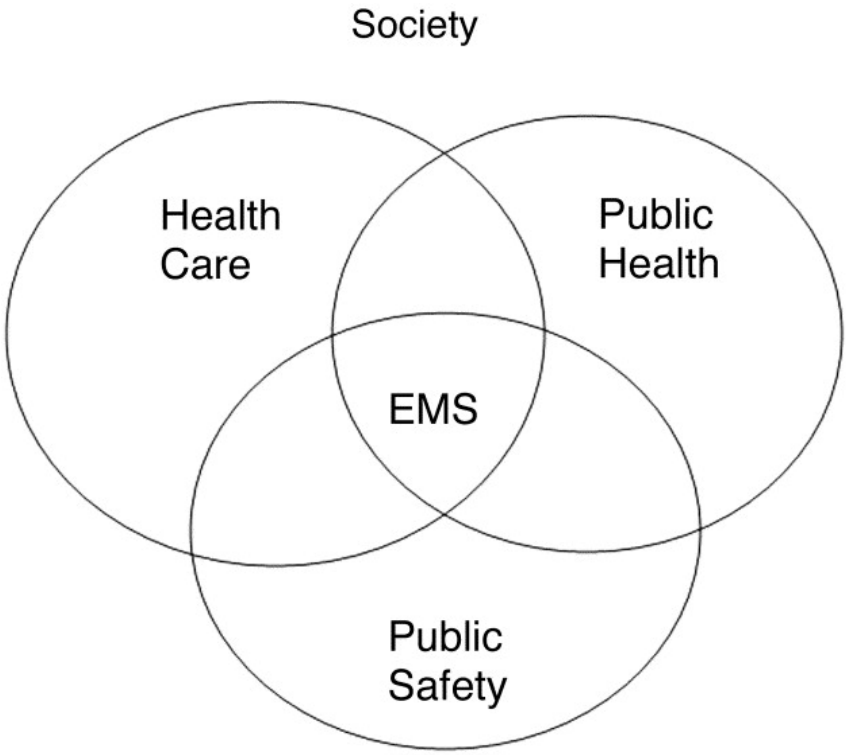

Figure 1. The overlapping roles and responsibilities of EMS.

The Cost-effectiveness of Prehospital Cardiac Care

Once total costs and benefits of EMS systems or interventions have been identified and monetized, opportunities to cut cost without losing benefits can be assessed and estimates of cost-effectiveness can be made. Although few studies have been published on the costs of EMS, out-of-hospital cardiac care is one area in which there is a growing body of literature.

Developing and implementing STEMI systems requires a substantial investment of resources for an EMS system. The direct cost of prehospital ECG equipment with monitoring and defibrillation capability ranges from $9,000 to $25,000 per vehicle. Other substantial expenses include direct and indirect costs for training, quality assurance, and organizing complex EMS and hospital systems required to efficiently acquire, interpret, and transmit prehospital ECGs.[12] According to a survey of 5,400 EMS Directors conducted by the American Heart Association,

only half the EMS systems have 12-lead ECG on 75% or more of their vehicles; of those systems with 12-lead ECGs, most had no standard method to deliver the ECG to the hospital.[133]

In most situations, ambulance services are reimbursed based on the level of care and mileage, not for specific services provided. Therefore, ambulance services are not reimbursed for the additional expense of developing a prehospital ECG and STEMI program. Current reimbursement levels are inadequate to cover the costs of initiating new STEMI programs and new financing methodologies must be developed.[8] Analysis of the cost of providing this service to the community must include consideration of the demonstrated benefits of more rapid treatment of patients with STEMI and the resulting time savings advantage shown to accompany the use of prehospital 12-lead ECG programs.[26]

Ambulance services considering purchasing 12 lead ECG capabilities may require reimbursement and potentially regulatory changes to encourage and mandate a standard of cardiac care. Authority and funding for STEMI programs may need to come from higher levels of government, such as county, state, or regional health agencies. Increasingly, health agencies at these regulatory levels are recognizing the importance of timely therapy for patients with STEMI and categorizing them similar to trauma patients. This emphasis on rapid treatment and the expansion of primary PCI to more hospitals may allow for funding of programs for prehospital ECGs to be tied in as well.[12]

Estimations of the costs of STEMI patients should include the financial impact that transport of STEMI patients directly to PCI-capable hospitals will have on the PCI centers, local hospitals that are bypassed, and on the EMS system. The bypassed facility faces a potential loss of income and EMS systems may need to acquire additional resources and training. Rural communities with a limited number of ambulances may experience temporary depletion of healthcare resources during lengthy transports. Currently, there are no cost-effectiveness models to evaluate the prehospital 12-lead ECG technology from the different perspectives of patients, hospitals, payers, and society.[12]

A common way to measure the cost-effectiveness of a medical intervention is to estimate the cost of the intervention per life saved or per quality-adjusted life year (QALY) saved. A cost effectiveness ratio of less than $50,000 per life-year is typically regarded as economically attractive, and ratios greater than $100,000 are considered economically unattractive. Such an approach has been used to measure the cost-effectiveness of automatic external defibrillation for patients in cardiac arrest[134,135,136] and for thrombolysis for patients with acute ischemic stroke.[137,138]

Van Alem and colleagues estimated the costs of resuscitation and care of cardiac arrest survivors for the first six months post-arrest in the Netherlands, comparing costs by time from collapse to first defibrillation.[136] Patients who received the quickest defibrillation (less than 7 min) experienced the highest survival rate (46%) and sustained the lowest costs of survivors. The intermediate time to shock group had a 26 percent survival rate, but is the most expensive group since these patients are in the hospital longer and require the most services. The late defibrillation group has a low survival rate of 13 percent and these patients often died within the first six months, decreasing the overall cost as compared to the intermediate group. Costs per survivor were lowest for the shortest time to shock group because of their shorter stay in the

intensive care unit.[136] Similarly, the implementation of a police-based AEDs was associated with a median cost of $27,200 per additional quality-adjusted life-year (QALY) saved, consistent with the cost of other common medical interventions.[134] Yen, et al., also found defibrillation to be most cost effective when administered within 7 min of symptom onset. [139] It should be noted when considering international studies, that estimates of cost-effectiveness for a specific intervention will improve as incidence rate for the condition under study and willingness to pay for preserving a life increase.

Cost-Effectiveness of Other Prehospital Interventions

Cost effectiveness analyses of thrombolysis for patients with acute ischemic stroke have been promising, indicating a high probability of a gain in quality-adjusted survival during the first year, with a lifetime cost-saving of $157,000 (£96,500) per quality-adjusted life year (QALY), however the assumptions employed in the economic model lead to a high level of imprecision in the estimates.[137,138] Other studies have shown promising, but similarly non-definitive results, when considering longer-term computations of cost effectiveness of this intervention.[140],[141]

Hubble and colleagues developed a theoretical model and estimated the reduction in hospitalization costs per CPAP application to be $4,075.[142] There can be little doubt that CPAP is an EMS intervention that reduces healthcare costs due to obviating the need to intubate and improving response to in-hospital treatments. It is a sizable investment to implement CPAP capabilities into an EMS system. However, CPAP is not a reimbursable item under current EMS payment methodologies and has inhibited many EMS systems from incorporating CPAP into their regular practice. In this subset of EMS patients, the scope of care has a direct, statistically significant improvement in patient outcomes and an overall decrease in healthcare cost.

The use of paramedic practitioners to treat acute minor medical emergencies in the elderly in England was found to be cost effective, reducing the proportion of patients who required treatment in the emergency department (53.3% vs. 84.0%) and decreased time spent in the ED (127 min vs. 211 min).[143] Overall, the paramedic practitioner treatment was found to be cost effective; taken in tandem with the clinical findings, the authors recommended wider implementation and evaluation of similar treatment schemes.

Although research in the costs of prehospital interventions is limited in scope, study findings consistently indicate the cost-effectiveness of the treatments studied to date and suggest that high-quality prehospital care not only improves health outcomes, but that it also is cost effective compared to competing interventions.

Conclusions

This paper documents the impact on health outcomes and healthcare costs of EMS systems and specific interventions. Based on these findings, the National EMS Advisory Council concludes:

- EMS makes a difference by producing clinically meaningful reductions in time to definitive treatment and improved health outcomes for patients with STEMI. Trained EMS providers are proficient in the capture and interpretation of 12-lead ECGs, can and

should make or participate in triage decisions to bypass closer hospitals in favor of to PCI-capable facilities, when clinically indicated. Efforts should continue to educate the public to call 9-1-1 at the first sign of a heart attack.

- EMS makes a difference by decreasing the times to CPR and defibrillation, defined as the two critical factors for surviving cardiac arrest.

- EMS makes a difference and is a critical component of effective stroke care. EMS must advocate for quality, standardized stroke protocols, performance improvement systems and training, and expedient transport of stroke patients to specialty care centers. EMS systems must partner with their dispatch agencies to ensure the use of quality Emergency Medical Dispatch protocols that provide proper stroke care instructions and activate appropriate resources. Efforts should continue to educate the public to call 9-1-1 at the first sign of a stroke.

- EMS makes a difference by improving survival and neurological function for patients with respiratory emergencies. Proper prehospital care decreases the need for intubations and the number of required hospital admissions and improves cerebral performance in patients with respiratory distress. The addition of CPAP to the EMS tool kit provides immediate and longer-term benefits and further reduces hospitalization rates and healthcare costs.

- EMS makes a difference by allowing EMS providers to use diagnostic tools such as blood glucometry, pulse oximetry, and 12-lead ECGs to efficiently evaluate patients and determine whether more advanced evaluation is necessary.

- EMS makes a difference by treating many diabetic patients at home without the need for transport; thereby improving patient satisfaction and decreasing healthcare costs.

- EMS makes a difference by accurately identifying patients experiencing out-of-hospital cardiac arrest who have no realistic chance of survival and determining whether transport to a hospital is warranted, thus reducing transports, decreasing hospital and patient costs, and increasing the availability of EMS resources.

- EMS makes a difference with its expanding role in the healthcare system. EMS has the potential to provide improved patient outcomes and more customer satisfying primary care while offering clinically appropriate alternatives to hospital transport in addition to standard 9-1-1 responses. In a fully integrated healthcare system, EMS will provide preventive services, acute care, and overall community health.

- EMS makes a difference in trauma care by providing rapid assessment, early notification to trauma centers, and rapid triage and transport to trauma centers, when appropriate. EMS will continue to be the community's safety net.

- EMS makes a difference with pediatric shock patients when shock is recognized and treated aggressively. The healthcare system must advocate for a systems approach to

pediatrics similar to trauma, STEMI, and stroke systems of care and standardized training for all healthcare providers.

The NEMSAC believes there is enough evidence to support the fact that EMS in general and certain interventions in the prehospital care of patients positively impact the clinical outcome of the patient in the short term and long term and have been shown to be cost effective. Meaningful healthcare reform cannot ignore the significant role of EMS in improving health outcomes and lowering healthcare expenditures.

More research in EMS is underway. The field of EMS has made significant strides in defining activities and developing performance measures to evaluate EMS systems. Research in the area of EMS finance is still limited. The current literature identifies a conceptual model for determining EMS system costs and indicates that EMS makes a difference in reducing downstream healthcare costs. However, many of the interventions identified in this document are cost prohibitive with current EMS reimbursement practices. The healthcare system must reevaluate the payment methodology of EMS to fully implement and integrate EMS into healthcare. The NEMSAC recommends that systems and cost-effectiveness research be conducted to assist EMS agencies, government and commercial insurance carriers, federal officials, and Congress to better realize actual costs for EMS systems, improve the EMS bottom line to accommodate changing conditions and medical advancements, and integrate EMS in the broader healthcare system. The end result will be better patient outcomes and decreased overall healthcare costs.

References

[1] Arreola-Risa C, Vargas J, Contreras I, and Mock C. Effect of emergency medical technician certification for all prehospital personnel in a Latin American city. J Trauma 2007; 63:914-9.

[2] Ghosh R, Pepe P. The critical care cascade: a systems approach. Curr Opin Crit Care 2009; 15:279-283.

[3] Cummins RO, Ornato JP, Thies WH, Pepe PE. Improving survival from sudden cardiac arrest: the chain of survival concept. Circulation 1991; 83:1832-1847.

[4] Eisenberg M, Psaty B. Defining and improving survival rates from cardiac arrest in US communities. JAMA, Feb 2009; 301(8):860-862.

[5] Lloyd-Jones D, Adams R, Carnethon M, De Simone G, Ferguson TB, Flegal K, et al. Heart Disease and Stroke Statistics 2009 Update: A Report from the American Heart Association Statistics Committee and Stroke Statistics Subcommittee. Circulation 2009; 119;e21-e181. Available at http://circ.ahajournals.org/cgi/reprint/CIRCULATIONAHA.108.191261 [accessed 10 Dec 2009]. This document reports 1,365,000 unique hospitalizations for acute coronary syndrome (ACS) in the US in 2006; STEMI events are reported to account for between 29% and 47% of ACS.

[6] Boden WE, Eagle K, Granger CB. Reperfusion strategies in acute ST-segment elevation myocardial infarction: a comprehensive review of contemporary management options.

[7] Caudle JM, Piggott Z, Dostaler S, Graham K, Brison RJ. Impact of a rapid access protocol on decreasing door-to-balloon time in acute ST elevation myocardial infarction. CJEM 2009; 11:20-35.

[8] Moyer P, Ornato JP, Brady WJ Jr, Davis LL, Ghaemmaghami CA, Gibler WB, Mears G, et al. Development of systems of care for ST-elevation myocardial infarction patients: the emergency medical services and emergency department perspective. Circulation 2007; 116: e43-8.

[9] De Luca G, Suryapranata H, Ottervanger JP, Antman EM. Time delay to treatment and mortality in primary angioplasty for acute myocardial infarction: every minute of delay counts. Circulation 2004; 109:1223-1225.

[10] Antman EM, Hand M, Armstrong PW, Bates ER, Green LA, Halasyamani LK, Hochman JS, Krumholz HM, Lamas GA, Mullany CJ, Pearle DL, Sloan MA, Smith SC Jr; 2004 Writing Committee Members, Anbe DT, Kushner FG, Ornato JP, Jacobs AK, Adams CD, Anderson JL, Buller CE, Creager MA, Ettinger SM, Halperin JL, Hunt SA, Lytle BW, Nishimura R, Page RL, Riegel B, Tarkington LG, Yancy CW. 2007 Focused Update of the ACC/AHA 2004 Guidelines for the Management of Patients With ST-Elevation Myocardial Infarction: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines: developed in collaboration with the Canadian Cardiovascular Society, endorsed by the American Academy of Family Physicians: 2007 Writing Group to Review New Evidence and Update the ACC/AHA 2004 Guidelines for the Management of Patients With ST-Elevation Myocardial Infarction, Writing on Behalf of the 2004 Writing Committee. *Circulation.* 2008; 117: 296–329.

[11] ECC Committee, Subcommittees and Task Forces of the American Heart Association. 2005 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. *Circulation.* 2005; 112 (suppl IV): IV-1–IV-203.

[12] Ting HH, Krumholz HM, Bradley EH, Cone DC, Curtis JP, Drew BJ, et al. Implementation and integration of prehospital ECGs into systems of care for acute coronary syndrome: a scientific statement from the American Heart Association Interdisciplinary Council on Quality of Care and Outcomes Research, Emergency Cardiovascular Care Committee, Council on Cardiovascular Nursing, and Council on Clinical Cardiology. Circulation, Sep 2008; 118: 1066-1079.

[13] Hutter AM Jr, Weaver WD. 31st Bethesda Conference: Emergency Cardiac Care: Task Force 2: acute coronary syndromes: section 2A: prehospital issues. *J Am Coll Cardiol.* 2000; 35: 846–853.

[14] Lau J, Ioannidis JP, Balk E, Milch C, Chew P, Terrin N, Lang TA, Salem D, Wong JB. Evaluation of technologies for identifying acute cardiac ischemia in emergency departments. *Evid Rep Technol Assess (Summ).* Sept 2000: 1–4.

[15] Williams DM. *JEMS* 200-city survey: a benchmark for the EMS industry [published corrections appear in *JEMS*. April 2006; 31:20 and June 2006; 31:17]. *JEMS*. Feb 2006; 31:44-61, 100–101.

[16] Kereiakes DJ, Gibler WB, Martin LH, Pieper KS, Anderson LC. Relative importance of emergency medical system transport and the prehospital electrocardiogram on reducing hospital time delay to therapy for acute myocardial infarction: a preliminary report from the Cincinnati Heart Project. *Am Heart J.* 1992; 123 (pt 1): 835–840.

[17] Brainard AH, Raynovich W, Tandberg D, Bedrick EJ. The prehospital 12-lead electrocardiogram's effect on time to initiation of reperfusion therapy: a systematic review and meta-analysis of existing literature. *Am J Emerg Med.* 2005; 23: 351–356.

[18] Racht EM. Prehospital 12-lead ECG: an evolving standard of care in EMS systems. *Emerg Med Serv.* 2001; 30: 105–107.

[19] Kudenchuk PJ, Maynard C, Cobb LA, Wirkus M, Martin JS, Kennedy JW, Weaver WD. Utility of the prehospital electrocardiogram in diagnosing acute coronary syndromes: the Myocardial Infarction Triage and Intervention (MITI) Project. *J Am Coll Cardiol.* 1998; 32: 17–27.

[20] Canto JG, Rogers WJ, Bowlby LJ, French WJ, Pearce DJ, Weaver WD; National Registry of Myocardial Infarction 2 Investigators. The prehospital electrocardiogram in acute myocardial infarction: is its full potential being realized? *J Am Coll Cardiol.* 1997; 29: 498–505.[

[21] Chawla N, Moyer P, and the Boston STEMI Investigators. How accurate is paramedic identification of ST segment elevation myocardial infarction in the prehospital setting? *Ann Emerg Med.* 2005; 46 (suppl): 8A. [Abstract.]

[22] Le May MR, So DY, Dionne R, Glover CA, Froeschi MP, Wells GA, Davies RF, et al. A citywide protocol for primary PCI in ST-segment elevation myocardial infarction. N Engl J Med 2008: 358(3):231-40.

[23] Le May MR, Dionne R, Maloney J, et al. Diagnostic performance and potential clinical impact of advanced care paramedic interpretation of ST-segment elevation myocardial infarction in the field. CJEM 2006; 8(6):401-407.

[24] van 't Hof AW, Rasoul S, van de Wetering H, et al. Feasibility and benefit of prehospital diagnosis, triage, and therapy by paramedics only in patients who are candidates for primary angioplasty for acute myocardial infarction.Am Heart J. 2006 Jun; 151(6):1255.e1-5.

[25] Provo TA, Frascone RJ. 12 lead Electrocardiograms during Basic Life Support Care. Prehospital Emergency Care 2004; 8(2): 212-216.

[26] Garvey JL, MacLeod BA, Sopko G, and Hand MM. Pre-hospital 12 lead electrocardiography programs: a call for implementation by emergency medical services systems providing advanced life support--National Heart Attack Alert Program (NHAAP) Coordinating Committee; National Heart, Lung, and Blood Institute (NHLBI); National Institutes of Health. J Am Coll Cardiol, Feb 2006; 47: 485-491.

[27] Gross BW, Dauterman KW, Moran MG, et al. An approach to shorten time to infarct artery patency in patients with ST-segment elevation myocardial infarction. Am J Cardiol 2007; May 15; 99(10):1360-1363. Epub 2007 Apr 5. 06; May; 27(10):1146-1152. Epub 2006 Apr 19.

[28] Bjorklund E, Stenestrand U, Lindback J, Svensson L, Wallentin L, Lindahl B. pre-hospital thrombolysis delivered by paramedics is associated with reduced time delay and mortality in ambulance-transported real-life patients with ST-elevation myocardial infarction. Eur Heart J 2006; 27:1146-11152.

[29] Cabrita, F Bouyer-Dalloz, I L'Huillier, et al. Beneficial effects of direct call to emergency medical services in acute myocardial infarction. Eur J Emerg Med, Feb 2004; 11:12-18.

[30] The American Heart Association in collaboration with the International Liaison Committee on Resuscitation. Guidelines 2000 for cardiopulmonary resuscitation and emergency cardiovascular care, part 6: advanced cardiovascular life support: section 7: algorithm approach to ACLS emergencies: section 7A: principles and practice of ACLS. *Circulation.* 2000; 102 (suppl I): I-136–I-139.

[31] Antman EM, Anbe DT, Armstrong PW, Bates ER, Green LA, Hand M, Hochman JS, Krumholz HM, Kushner FG, Lamas GA, Mullany CJ, Ornato JP, Pearle DL, Sloan MA, Smith SC Jr, Alpert JS, Anderson JL, Faxon DP, Fuster V, Gibbons RJ, Gregoratos G, Halperin JL, Hiratzka LF, Hunt SA, Jacobs AK; American College of Cardiology/American Heart Association Task Force on Practice Guidelines; Canadian Cardiovascular Society. ACC/AHA guidelines for the management of patients with ST-elevation myocardial infarction: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (Committee to Revise the 1999 Guidelines for the Management of Patients With Acute Myocardial Infarction) [published corrections appear in *Circulation*. 2005; 111:2013–2014 and 2007; 115:e411]. *Circulation.* 2004; 110: e82–292.

[32] Marenco JP, Wang PJ, Link MS, Homoud MK, and Estes NA 3rd. Improving survival from sudden cardiac arrest: the role of the automated external defibrillator. Jama 2001; 286(1):47.

[33] Weaver WD, Cobb, LA, Hallstrom AP. Factors influencing survival after out-of-hospital cardiac arrest. J Am Coll Cardiol 1986; 7:752-755.

[34] O'Rourke MF, Donaldson EE, Geddes JS. An airline cardiac arrest program. *Circulation.* 1997; 96:2849-2853.

[35] Page RL, Joglar JA, Kowal RC, et al. Use of automated external defibrillators by a U.S. airline. *N Engl J Med.* 2000; 343:1210-1216.

[36] Mossesso VN Jr, Davis EA, Auble TE, Paris PM, Yealy DM. Use of automated external defibrillators by police officers for treatment of out-of-hospital cardiac arrest. *Ann Emerg Med.* 1998; 32:200-207.

[37] Weaver WD, Copass MK, Bufi D, Ray R, Hallstrom AP, Cobb LA. Improved neurologic recovery and survival after early defibrillation. *Circulation.* 1984; 69:943-948.

[38] White RD, Vukov LF, Bugliosi TF. Early defibrillation by police: initial experience with measurement of critical time intervals and patient outcome. Ann Emerg Med. 1994; 23:1009-1013.

[39] Weaver WD, Hill D, Fahrenbuch CE, et al. Use of automated external defibrillators in the management of out-of-hospital cardiac arrest. *N Engl J Med.* 1988; 319:661-666.

[40] Stults KR, Brown DD, Kerber RE. Efficacy of an automated external defibrillator in the management of out-of-hospital cardiac arrest: validation of the diagnostic algorithm and the clinical experience in a rural environment. *Circulation.* 1986; 73:701-709.

[41] Cummins RO, Eisenberg MS, Litwin PE. Automatic external defibrillators used by emergency medical technicians: a controlled clinical trial. *JAMA.* 1987; 257:1605-1610.

[42] Newman MM, Mosesso VN Jr, Ornato JP, Paris PM, and the National Center for Early Degibrillation Police AED Issues Forum. Law enforcement agency defibrillation: position statement and best practices recommendations from the National Center for Early Defibrillation. Resuscitation 2002; 54:11-14.

[43] Hoyer CB, Christensen EF. Fire fighters as basic life support responders: A study of successful implementation. *Scand J Trauma Resusc Emerg Med* 2009 17(1):16.

[44] Shuster M, Keller JL. Effect of fire department first-responder automated defibrillation. *Ann Emerg Med.* 1993; 22:721-727.

[45] Nichol G, Stiell IG, Laupacis A, et al. A cumulative meta-analysis of the effectiveness of defibrillator-capable emergency medical services for victims of out-of-hospital cardiac arrest. *Ann Emerg Med.* 1999; 34:517-525.

[46] Kellermann AL, Hackman BB, Somes G, Kreth TK, Nail L, Dobyns P. Impact of first-responder defibrillation in an urban emergency medical services system. *JAMA.* 1993; 270:1708-1713.

[47] Sweeney TA, Runge JW, Gibbs JM, Schafermeyer RW, Norton HJ, Boyle-Whitesel MJ. EMT defibrillation does not increase survival from sudden cardiac death in a two-tiered urban-suburban EMS system. *Ann Emerg Med.* 1998; 31:234-240.

[48] Weaver WD, Copass MK, Hill D, Fahrenbruch C, Hallstrom AP, Cobb L. Cardiac arrest treated with a new automatic external defibrillator by out-of-hospital first responders. *Am J Cardiol.* 1986; 57:1017-1021.

[49] Cappato R, Curnis A, Marzollo P, et al. Prospective assessment of integrating the existing emergency medical system with automated external defibrillators fully operated by volunteers and laypersons for out-of-hospital cardiac arrest: the Brescia Early Defibrillation Study (BEDS). Eur. Heart J., Mar 2006; 27: 553-561.

[50] American Heart Association. Stroke Statistics. Dallas (TX): American heart Association; 2009. http://www.americanheart.org/presenter.jhtml?identifier=4725. Accessed November 2009.

[51] Centers for Disease Control and Prevention. State-specific mortality from stroke and distribution of place of death — United States, 1999. MMWR Morb Mortal Wkly Rep 2002:51(20); 429-433.

[52] Williams M, Patil S, Toledo EG, Vannemreddy P. Management of acute ischemic stroke: current status of pharmacological and mechanical endovascular methods. Neurol Res 2009; 31:807-815.

[53] Wardlaw JM, Zoppo G, Yamaguchi T, Berge E. Thrombolysis for acute ischaemic stroke. Cochrane Database Syst Rev 2003; (3):CD000213.

[54] Centers for Disease Control and Prevention (CDC). Prehospital and hospital delays after stroke onset—United States 2005-2006. MMWR Morb Mortal Wkly Rep. 2007 May 18; 56(19):474-478.

[55] Saddichha S, Saxena MK, Vibha P, Methuku M. Neurological emergencies in India – lessons learnt and strategies to improve outcomes. Neuroepidemiology 2009; 33:280-285.

[56] Williams I, Mears G, Raisor C, Wilson J. An emergency medical services toolkit for improving systems of care for stroke in North Carolina. Prev chronic Dis 2009; 6:A67.

[57] Smith MA, Doliszny KM, Shahar E, McGovern PG, Arnett, DK, Luepker RV. Delayed hospital arrival for acute stroke: the Minnesota Stroke Survey. Ann Intern Med 1998; 129:190-196.

[58] Rosamond WD, Gorton RA, Hinn AR, Hohenhaus SM, Morris DL. Rapid response to stroke symptoms: the Delay in Accessing Stroke Healthcare (DASH) study. Acad Emerg Med 1998; 5:45-51.

[59] Morris KL, Rosamond W, Madden K, Schultz C, Hamilton S. Prehospital and emergency department delays after acute stroke: the Genentech Stroke Presentation Survey. Stroke 2000; 31:2585 -2590.

[60] Millin MG, Gullett T, Daya MR. EMS management of acute stroke—out-of-hospital treatment and stroke system development (resource document to NAEMSP position statement). Prehosp Emerg Care 2007; 11:318-325.

[61] Brice JH, Griswell JK, Delbridge TR, Key CB. Stroke: from recognition by the public to management services. Prehosp Emerg Care 2002; 6:99-106.

[62] Reeves MJ, Arora S, Broderick JP, Frankel M, Heinrich JP, Hickenbottom S, et al. Acute stroke care in the US: results from four pilot prototypes of the Paul Coverdell National Acute Stroke Registry. [Published erratum in: Stroke 2005; 36:1820]. Stroke 2005; 36:1232-1240.

[63] National Association of EMS Physicians Position Statement. The role of EMS in the management of acute stroke: triage, treatment, and stroke systems. Prehosp Emerg Care 2007; 11:312.

[64] Chenkin J, Gladstone DJ, Verbeek PR, Lindsay P, Fang J, Black SE, Morrison L. Predictive value of the Ontario prehospital stroke screening tool for the identification of patients with acute stroke. Prehosp Emerg Care 2009; 13:153-159.

[65] Ramanujam P, Guluma KZ, Castillo EM, Chacon M, Jensen MB, Patel E, Linnick W, Dunford JV. Accuracy of stroke recognition by emergency medical dispatchers and paramedics – San Diego experience. Prehosp Emerg Care 2008; 12:307-313.

[66] Whelley-Wilson CM, Newman GC. A stroke scale for emergency triage. J Stroke Cerebrovasc Dis 2004; 13:247-253.

[67] Llanes JN, Kidwell CS, Starkman S, Leary MC, Eckstein M, Saver JL. The Los Angeles Motor Scale (LAMS): a new measure to characterize stroke severity in the field. Prehosp Emerg Care 2004; 8:46-50.

[68] Tirschwell DL, Longstreth WT Jr, Becker KJ, Gammans RE Sr, Sabounjian LA, Hamilton S, Morgenstern LB. Shortening the NIH Stroke scale for use in the prehospital setting. Stroke 2002; 33:2801-2806.

[69] Wojner-Alexandrov AW, Alexandrov AV, Rodriguez D, Persse D, Grotta JC. Houston paramedic and emergency stroke treatment and outcomes study(PhPSTO). Stroke 2005; 36:1512-1518.

[70] Gropen T, Magdon-Ismail Z, Day D, Melluzzo S, Schwamm LH, NECC Advisory Group. Regional implementation of the stroke systems of care model: recommendations of the northeast cerebrovascular consortium. Stroke 2009; 40:1793-1802.

[71] McNamara MJ, Oser C, Gohdes D, Fogle CC, Dietrich DW, Burnett A, et al. Stroke knowledge among urban and frontier first responders and emergency medical technicians in Montana. J Rural Health 2009; 24:189-193.

[72] Leira EC, Hess DC, Torner JC, Adams HP Jr. Rural-urban differences in acute stroke management practices: A modifiable disparity. Arch Neurol 2008; 65:887-891.

[73] Brice JH, Evenson KR, Lellis JC, Rosamond WD, Aytur SA, Christian JB, Morris DL. Emergency medical services education, community outreach, and protocols for stroke and chest pain in North Carolina. Prehosp Emerg Care 2008; 12:366-371.

[74] Quain DA, Parsons MW, Loudfoot AR, Spratt NJ, Evans MK, Russell ML, et al. Imroving access to acute stroke therapies: a controlled trial of organised pre-hospital and emergency care. Med J Aust 2008; 189:429-233.

[75] Abdullah AR, Smith EE, Biddinger PD, Kalenderian D, Schwamm LH. Advance hospital notification by EMS in acute stroke is associated with shorter door-to-computed tomography time and increased likelihood of administration of tissue-plasminogen activator. Prehosp Emerg Care 2008; 12:426-431.

[76] Gladstone DJ, Rodan LH, Sahlas DJ, Lee L, Murray BJ, Ween JE, et al. A citywide prehospital protocol increases access to stroke thrombolysis in Torondo. Stroke 2009:40:3841-3844.

[77] California Acute Stroke Pilot Registry (CASPR) Investigators. Prioritizing interventions to improve rates of thrombolysis for ischemic stroke. Neorulogy 2005; 64: 654-659.

[78] Tadros A, Crocco T, Davis SM, Newman J, Mullen, Best R, et al. Emergency medical services-based community stroke education: pilot results from a novel approach. Stroke 2009; 40:134-142.

[79] Acker JE 3rd, Pancioli AM, Crocco TJ, et al. Implementation strategies for emergency medical services within stroke systems of care: a policy statement from the American Heart Association/American Stroke Association Expert Panel on Emergency Medical Services Systems and the Stroke Council. Stroke, Nov 2007; 38: 3097-115.

[80] McCaig LF, Ly N. National Hospital Ambulatory Medical Care Survey: 2000 emergency department summary. Advance data from vital and health Statistics. No. 326. DHHS publication no. (PHS) 2002-1250-0259. Hyattsville, MD: National Center for Health Statistics 2002.

[81] Stiell IG, Spaite DW, Field B, Nesbitt LP, Munkley D, Maloney J, et al. Advanced life support of out-of-hospital respiratory distress. N Engl J Med 2007; 356:2156-2164.

[82] Gray A, Coodacre S, Newby DE, Masson M, Sampson F, Nicholl J, 3CPO Trialists. Noninvasive ventilation in acute cardiogenic pulmonary edema. N Engl J Med 2008; 359:142-151.

[83] Kosowsky JM, Stephanides SL, Branson RD, Sayre MR. Prehospital use of continuous positive airway pressure (CPAP) for presumed pulmonary edema: a preliminary case series. Prehosp Emerg Care 2001; 5:190-196.

[84] Plaisance P, Pirracchio R, Berton C, Vicaut E, Payen D. A randomized study of out-of-hospital continuous positive airway pressure for acute cardiogenic pulmonary oedema: physiological and clinical effects. Europ Heart J 2007; 28:2895-2901.

[85] Winck WC, Azevedo LF, Costa-Pereira A, Antonelli M, Wyatt JC. Efficacy and safety of non-invasive ventilation in the treatment of acute cardiogenic pulmonary edema-a systemic review and meta-analysis. Critical Care 2006: 10:R69.

[86] Institute of Medicine. Future of Emergency Care: Emergency Medical Services at the Crossroads. National Academy Press; Washington, DC, 2007.

[87] Stiell IG, Nesbitt LP, Pickett W, and OPALS Study Group. The OPALS Major Trauma Study: impact of advanced life-support on survival and morbidity. Can. Med. Assoc. J., Apr 2008; 178: 1141-1152.

[88] Institute of Medicine. Reducing the Burden of Injury. National Academy Press: Washington, DC, 1999.

[89] National Highway Traffic Safety Administration. Trauma System Agenda for the Future. DOT HS 809 675. U.S. Department of Transportation: Washington, DC, 2004.

[90] Mackenzie E, Rivara F, Jurkovich G, Nathens A, Frey K, Egleston B, Salkever D, Scharfstein D, A National Evaluation of the Effect of Trauma-Center Care on Mortality. N. Engl J Med 2006; 354:366-378.

[91] The Brain Trauma Foundation: Guidelines for prehospital management of traumatic brain injury, 2nd Edition. Prehosp Emerg Care 2007 12(Suppl):S1-S52.

[92] Watts DD, Hanfling D, Waller MA, Gilmore C, Gakhry SM, Trask AL. An evaluation of the use of guidelines in prehospital management of brain injury. Prehosp Emerge Care 2004; 8:254-261.

[93] Lenartova L, Janciak I, Wilbacher I, Rusnak M, Mauritz W, and the Austrian Severe TBI Study Investigators. Severe traumatic brain injury in Austria III: prehospital status and treatment. Wien Klin Wochenschr 2007; 119:35-45.

[94] Berlot G, La Fata C, Bacer B, Biancardi B, Viviani M, Lucangelo U, et al. Influence of prehospital treatment on the outcome of patients with severe blunt traumatic brain injury: a single-centre study. Eur J Emerg Med 2009; 16:312-317.

[95] Utter GH, Maier RV, Rivara FP, Nathens AB. Outcomes after ruptured abdominal aortic aneurysms: the "halo effect" of trauma center designation. J Am Coll Surg 2006; 203:498-505.

[96] Haas B, Jurkovich GJ, Wang J, Rivara FP, MacKenzie EJ, Nathens AB. Survival advantage in trauma centers: expeditious intervention or experience? J Am Coll Surg 2009; 208:28-36.

[97] Nathens AB, Jurkovich GJ, Maier RV, Grossman DC, MacKenzie EJ, Moore M, Rivara FP. Relationship between trauma center volume and outcomes. JAMA 2001; 285:1164-1171.

[98] Sasser SM, Hunt RC, Sullivent EE, Wald MM, Mitchko J, Jurkovich GJ, et al. Guidelines for field triage of injured patients. Recommendations of the National expert Panel on field triage. MMWR Recomm Rep 2009; 58(RR-1):1-35.

[99] Norcross ED, Ford DW, Cooper ME, Zone-Smith L, Byrne TK, Yarbrough DR 3rd. Application of American College of Surgeons' field triage guidelines by pre-hospital personnel. J Am Coll Surg. 1995; 181:539-544.

[100] Gausche M, Lewis RJ, Stratton SJ, Haynes BE, Gunter CS, Goodrich SM, et al. Effect of out-of-hospital pediatric endotracheal intubation on survival and neurologic outcome: a controlled clinical trial. JAMA 2000; 283:783-790.

[101] Carcillo J, Kuch B, Han Y, Day S, et al. Use of PALS /APLS by Community Physicians to Reverse All-cause Pediatric Shock is Associated with Reduced Mortality and Functional Morbidity: A Multicenter Cohort Study. Pediatrics, 2008-1967. R2.

[102] Brierley J, Carcillo JA, choong K, Cornell T, Decaen A, Deymann A, Doctor A, et al. clinical practice parameters for hemodynamic support of pediatric and neonatal septic shock: 2007 update from the American College of Critical Care Medicine. Crit Care Med 2009; 37:666-688.

[103] Oliveira CF, Nogueira de As FR, Oliveira DS, Gottschald AF, Moura JD, Shibata AR, et al. Time- and fluid-sensitive resuscitation for hemodynamic support of children in septic shock: barriers to the implementation of the American College of critical Care Medicine/Pediatric Advanced Life Support Guidelines in a pediatric intensive care unit in a developing world. Pediatr Emerg Care 2008; 24:810-815.

[104] Carcillo JA, Kuch BA, Han YY, Day S, Greenwald BM, McCloskey KA, et al. Mortality and functional morbidity after use of PALS/APLS by community physicians. Pediatr 2009; 124:500-508.

[105] Baker TW, King W, Soto W, Asher C, Stolfi A, Rowin ME. The efficacy of pediatric advanced life support training in emergency medical service providers. Pediatr Emerg Care 2009; 25:598-512.

[106] Cichon M, Fuchs S, Lyons E, & Leonard D. A Statewide model program to improve emergency department readiness for pediatric care. Ann Emerg Med 2009; 54:198-204..

[107] National Highway Traffic Safety Administration. Emergency Medical Services agenda for the Future. DOT HS 808 441. National Highway Traffic Safety Administration, Washington, DC, 1996.

[108] National Highway Traffic Safety Administration. The National EMS Scope of Practice Model. DOT HS 810 657. National Highway Traffic Safety Administration: Washington, DC, 2007.

[109] Strote J, Cloyd D, Rea T, and Eisenberg M. The influence of emergency medical technician glucometry on paramedic involvement. Prehosp Emerg Care, Jul 2005; 9: 318-321.

[110] Van Dyk NT Cloyd , DJ, Rea TD, and Eisenberg MS. The effect of pulse oximetry on emergency medical technician decision-making. Prehosp Emerg Care, Oct 2004; 8: 417-419.

[111] Cain E, Ackroyd-Stolarz S, Alexiadis P, Murry D. Prehospital hypoglycemia: the safety of not transporting treated patients. Prehosp Emerg Care 2003; 7:458-465.

[112] Socransky SJ, Pirrallo RG, Rubin JM. Out-of-hospital treatment of hypoglycemia: refusal of transport and patient outcome. Acad Emerg Med 1998; 5:1080-1085.

[113] Mason S, Knowles E, Colwell B, Dixon S, Wardrope J, Gorringe R, Snooks H, Perrin J, Nicholl J. Effectiveness of paramedic practitioners in attending 999 calls from elderly people in the community: cluster randomized controlled trial. BMJ. 2007 Nov 3; 335(7626):919.

[114] Richmond NJ, Silverman R, Kusick M, Matallana L, Winokur J. Out-of-hospital administration of albuterol for asthma by basic life support providers. Acad Emerg Med 2005; 12:396-403.

[115] Markenson D, Foltin G, Tunik M, Cooper A, Treiber M, Caravaglia K. Albuterol sulfate administration by EMS-basics: results of a demonstration project. Prehosp Emerg Care 2004; 8:34-40.

[116] Hale D, Sipprell K.Ability of EMT-Bs to determine which wounds can be repaired in the field. Prehosp Emerg Care. 2000 Jul-Sep; 4(3):245-249.

[117] Schaefer RA, Rea TD, Plorde M, Peiguss K, Goldberg P, Murray JA. An emergency medical services program of alternate destination of patient care. Prehosp Emerg Care. 2002 Jul-Sep; 6(3):309-314.

[118] Sasson C, Hegg AJ, Macy M, et al. Prehospital termination of resuscitation in cases of refractory out-of-hospital cardiac arrest. JAMA 2008; 300(12):1,432-38.

[119] Sherbino J, Keim SM, Davis DB, Best Evidence in Emergency Medicine (BEEM) Group. Clinical decision rules for termination of resuscitation of out-of-hospital cardiac arrest. J Emerg Med 2009 Oct 1. (Epub ahead of print].

[120] Morrison LJ, Verbeek PR, Zhan C, Kiss A, Allan KS. Validation of a universal prehospital termination of resuscitation clinical prediction rule for advanced and basic life support providers. Resuscitation 2009. 80:324-328.

[121] Morrison LJ, Visentin LM, Kiss A, Theriault R, Eby D, Vermeulen M, Sherbino J, Verbeek PR; TOR Investigators. Validation of a rule for termination of resuscitation in out-of-hospital cardiac arrest. N Engl J Med 2006; 355(5):478-87.

[122] Verbeek PR, Vermeulen MJ, Ali FH, et al. Derivation of a termination-of-resuscitation guideline for emergency medical technicians using automated external defibrillators. Acad Emerg Med 2002; 9(7):671-678.

[123] Rosamond W, Flegal K, Furie K, et al. Heart disease and stroke statistics—2008 update: report from the American Heart Association Statistics Committee and Stroke Statistics Subcommittee [published online ahead of print December 17, 2007]. *Circulation*. 2008; 117(4):e25-e146.

[124] Sasson C, Forman J, Krass D, Macy M, Kellermann AL and McNally BF. A Qualitative Study to identify barriers to local implementation of prehospital termination of resuscitation protocols. Cair Cardiovasc Qual Outcomes 2009; 2(4):361-368.

[125] Myers JB, Slovis CM, Eckstein M, Goodloe JM, Isaacs SM, Loflin JR, Mechem CC, Richmond NJ, Pepe PE, et al. Evidence-based performance measures for emergency medical services systems: a model for expanded EMS benchmarking. Prehosp Emerg Care, Apr 2008; 12: 141-51.

[126] National Association of State EMS Officials, Falls Church, VA. (http://www.nemsis.org/media/pdf/EMSPerformanceMeasuresFinalDraftforNHTSA12-06.pdf, 2009)

[119] Lerner EB, Maio RF, Garrison HG, Spaite DW, Nichol G. Economic value of out-of-hospital care: a structured literature review. Ann Emerg Med 2006; 47:515-524.

[128] Callaham M. Quantifying the scanty science of prehospital emergency care. Ann Emerg Med 1997; 30:785-790.

[129] Reines HD, Bartlett RL, Chudy NE, et al. Is advanced life support appropriate for victims of motor vehicle accidents: the South Carolina Highway Trauma Project. J Trauma. 1988; 28:563-570.

[130] Stiell IG, Wells GA, Spaite DW, et al., The Ontario Prehospital Advanced Life Support (OPALS) Study part II: rationale and methodology for trauma and respiratory distress patients: OPALS Study Group. Ann Emerg Med 1999; 34:256-262.

[131] Gold MR, Siegel JE, Russell LB, et al. Cost-effectiveness in Health and Medicine. New York, NY: Oxford University Press, 1996.

[132] Lerner EB, Nichol G, Spaite DW, et al. A comprehensive framework for determining the cost of an emergency medical services system. Ann Emerg Med, Mar 2007; 49: 304-13.

[133] American Heart Association. Mission: Lifeline www.httpsev.prnewswire.com/health-care-hospitals/20090216/DC7135816022009-1.html. [Accessed April 2009.]

[134] Nichol G, Huszti E, Birnbaum A, Mahoney B, Weisfeldt M, Travers A, Christenson, J, Kuntz K, PAD investigators. Cost-effectiveness of lay responder defibrillation for out-of-hospital cardiac arrest. Ann Emerg Med 2009; 54:226-35.

[135] Nichol G, Hallstrom AP, Ornato JP, et al. Potential cost-effectiveness of public access defibrillation in the United States. *Circulation.* 1998; 97:1315-1320.

[136] van Alem AP, Dijkgraaf MG, Tijssen JG, and Koster RW. Health system costs of out-of-hospital cardiac arrest in relation to time to shock. Circulation, Oct 2004; 110: 1967-73.

[137] Sandercock P, Berge E, Dennis M, Forbes J, Hand P, Kwan J, et al. A systematic review of the effectiveness, cost-effectiveness and barriers to implementation of thrombolytic and neuroprotective therapy for acute ischaemic stroke in the NHS. Health Technol Assess 2002; 6(26).

[138] Sandercock P, Berge E, Dennis M, Forbes J, Hand P, Kwan J, et al. Cost-effectiveness of thrombolysis with recombinant tissue plasminogen activator for acute ischemic stroke assessed by a model based on UK NHS costs. Stroke 1004; 35:1490-1498.

[139] Yen ZS, Chen YT, Ko PC, et al. Cost-effectiveness of different advanced life support providers for victims of out-of-hospital cardiac arrests. J Formos Med Assoc, Dec 2006; 105: 1001-7.

[140] Fagan SC, Morgenstern LB, Petitta A, Ward RE, Tilley BC, Marier JR, et al. Cost-effectiveness of tissue plasminogen activator for acute ischemic stroke. NINDS re-PA Stroke Study Group.l Neurology 1998; 50:883-890.

[141] Ehlers L, Andersen G, Clausen LB, Bech M, Kjolby M. Cost-effectiveness of intravenous thrombolysis with alteplase within a 3-hour window after acute ischemic stroke. Stroke 2007; 38:85-89.

[142] Hubble MW, Richards ME, Wilfong DA. Estimates of cost-effectiveness of prehospital continuous positive airway pressure in the management of acute pulmonary edema. Prehosp Emerg Care 2008; 12(3): 277-285.

[143] Dixon S, Mason S, Knowles E, Colwell B, Wardrope J, Snooks H, et al. Is it cost effective to introduce paramedic practitioners for older people to the ambulance service? Results of a cluster randomized controlled trial. Emerg Med J 2009; 26:226-251.