EMS PROVIDER AND PATIENT SAFETY DURING RESPONSE AND TRANSPORT: PROCEEDINGS OF AN AMBULANCE SAFETY CONFERENCE

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ABSTRACT

The out-of-hospital setting is unique to health care and presents many challenges to providing safe, high-quality medical care in emergency situations. The challenges of the prehospital environment require thoughtful design of systems and processes of care. The unique challenges of ambulance safety may be met by analyzing systems and incorporating process improvements. The purposes of this paper are to 1) outline the nature of this problem, 2) introduce a framework for this discussion, 3) provide expert opinion from a two-day ambulance safety conference, and 4) propose a plan of action to address the safety issues identified in the literature and expert opinion at the conference. Utilizing the Haddon Matrix as a framework, we present the safety issues and proposed solutions for factors contributing to an injury event in the emergency medical services (EMS) transport environment: host, agent, physical environment, and social environment. *Host* refers to the person or persons at risk, in this case, the EMS personnel or the patient. The *agent of injury* refers to the energy exerted during the course of an injury, and may be modified to include unrestrained

Received June 19, 2011, from the Department of Emergency Medicine, University of North Carolina at Chapel Hill (JHB), Chapel Hill, North Carolina; the Center for Prehospital Medicine (JRS) and the Mecklenburg EMS Agency (EH), Department of Emergency Medicine, Carolinas Medical Center, Charlotte, North Carolina; Rescu, Keenan Research Centre, Li KaShing Knowledge Institute, St Michael's Hospital (BLB, LJM), Toronto Ontario Canada; the Department of Emergency Medicine, University of Pittsburgh (CM-G), Pittsburgh, Pennsylvania; and the Department of Emergency Medicine, University of Virginia (CBC), Charlottesville, Virginia. Revision received September 13, 2011; accepted for publication September 19, 2011.

Presented at the National Association of EMS Physicians Ambulance Safety Conference, Phoenix, Arizona, January 2010.

Supported in part by unrestricted educational grants from Zoll Medical Corporation and Physio-Control to the National Association of EMS Physicians.

The authors would like to acknowledge the ambulance safety experts who provided their knowledge and expertise at the National Association of EMS Physicians Ambulance Safety Conference on January 5 and 6, 2010. These experts are listed at the end of this article.

Declaration of interest: Dr. Brice currently holds peer-reviewed grants from the National Highway Traffic Safety Administration and the Emergency Medical Services for Children program. Dr. Studnek received a stipend from the National Association of EMS Physicians through unrestricted grants from Zoll Medical Corporation and Physio-Control for this work. Mr. Bigham is employed by The Regional Municipality of York (paramedic), Ornge Transport Medicine (paramedic), and Centennial College (instructor). He has held peer-reviewed grants related to emergency medical services research funded by the EMS Chiefs of Canada, the Calgary EMS Foundation, the Canadian Patient Safety Institute, the Nova Scotia Health Research Foundation, the Canadian Institutes of Health Research, and Defence Research and Development Canada as an investigator at St. Michael's Hospital and the University of Toronto. He has provided paid consultation to the Canadian Medic Alert Foundation related to paramedic practice. Dr. Martin-Gill has held a peer-reviewed grant from the Society for Academic Emergency Medicine through an unrestricted grant from Physio-Control. Dr. Custalow has no disclosures to report. Dr. Hawkins received a stipend from the National Association of EMS Physicians through unrestricted grants from Zoll Medical Corporation and Physio-Control for this work. Dr. Morrison is the Toronto Principal Investigator for the Resuscitation Outcomes Consortium and Zoll Medical Corporation contributes in-kind support to the EMS services contributing to the Resuscitation Outcomes Consortium and unrestricted financial support to the Steering Committee meetings. Dr. Morrison currently holds peer-reviewed grants from Laerdal Medical Foundation, American Heart Association, Heart and Stroke Foundation of Canada, National Institute of Health, Canadian Institute of Health Research, National Defence, and Ontario Ministry of Health and Long-term Care. Dr. Morrison has completed peer-reviewed research on EMS patient safety funded by the EMS Chiefs of Canada, the Calgary EMS Foundation, and the Canadian Patient Safety Institute.

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doi: 10.3109/10903127.2011.626106

equipment that contributes to the injury. The *physical environment* refers to the characteristics of the setting in which the injury takes place, such as the roadway or the physical design of the ambulance. Finally, the *social environment* refers to the social, legal, and cultural norms and practices in the society, such as peer pressure and a culture that discourages the use of safety equipment. **Key words:** emergency medical services; transportation of patients; ambulance; safety; occupational health; emergency medical technicians

PREHOSPITAL EMERGENCY CARE 2012;16:3–19

INTRODUCTION

The out-of-hospital setting is unique to health care and presents many challenges to providing safe, high-quality medical care in emergency situations. When human resources are stressed or limited and environmental circumstances are dynamic and unpredictable, it is difficult for providers to execute perfect decisions consistently. The challenges of the prehospital environment require thoughtful design of systems and processes of care. The goal of these systems should be to reduce the burden on frontline providers by supporting them with the tools necessary to safely provide effective care.

The unique challenges of ambulance safety may be met by analyzing systems and incorporating process improvements. Emergency medical services (EMS) professionals in the United States treat 22 million patients each year,[1] and most of the care delivered by EMS involves the utilization of an ambulance, whether responding to a call or transporting patients to the hospital. There is a growing body of evidence to suggest that an ambulance is a difficult working environment fraught with hazards to both patients and providers. The purposes of this paper are to 1) outline the nature of this problem, 2) introduce a framework for this discussion, 3) provide expert opinion from a two-day ambulance safety conference, and 4) propose a plan of action to address the safety issues identified in the literature and expert opinion at the conference.

NATURE OF THE PROBLEM

Literature over the last two decades has indicated that riding in the back of an ambulance is associated with significant morbidity and mortality.[2–17] Maguire et al. have estimated an occupational fatality rate of 12.7 per 100,000 EMS workers each year, which is well above the national rate of 5.0 per 100,000 workers annually.[2]Additionally, they have estimated an EMS injury rate of 19.6 per 100 full-time workers, as compared with the national average of 7.0 per 100 full-time workers.[3,16] No one has estimated the risk of injury to patients during treatment and transport in a moving ambulance, but there is a growing body of knowledge describing patient safety threats in prehospital care.[18]

All occupants of emergency vehicles, providers and patients, are at risk for injury, no matter the status of the response or transport.[10,12,19] When EMS personnel are focused on care delivery and the driver is proceeding in an emergent fashion with lights and siren, the attendants in the rear of the vehicle are often standing and unrestrained.[20,21] A sudden stop, swerve, or crash may result in serious injury to the attendant and, quite possibly, the patient. Even when transporting patients to the hospital without lights and siren, ambulance personnel report the need to be unrestrained for approximately 40% of the transport.[22] One study indicated that 48% of emergency vehicle crashes occurred when the vehicle was not in a lights-and-siren mode,[10] and an analysis of the Fatality Analysis Reporting System database indicated that 31% of fatal ambulance crashes occurred in nonemergency mode.[4,12]

Whether we are transporting with lights and siren or without, it is time to examine EMS work safety in and around the ambulance, move to address the issues that are identified, and propose solutions to make EMS a safer environment for both providers and patients.

THE THEORETICAL FRAMEWORK

While serving as the first director of the United States National Highway Traffic Safety Administration, William Haddon, Jr., developed the Haddon Matrix to conceptualize injury prevention. He was both a physician and an engineer, and he saw how describing injuries from many angles could lead to a more complete picture of contributing factors and thus a more complete solution to the problem being analyzed.[23,24]

The four key components of the Haddon Matrix (Fig. 1) that relate to factors contributing to an injury event are the host, the agent, the physical environment, and the social environment.[25] The *host* refers to the person or persons at risk, in this case the EMS personnel or the patient. The *agent of injury* refers to the energy exerted during the course of an injury, and may be modified to include unrestrained equipment that contributes to the injury.[26] The *physical environment* refers to the characteristics of the setting in which the injury takes place, such as the roadway or the physical design of the ambulance. Finally, the *social environment* refers to the social, legal, and cultural norms and practices in the society, such as peer pressure and a culture that discourages the use of safety equipment. A second temporal dimension to the Haddon Matrix conveys information about the timing of factors that played a role in the event occurrence: preevent, event, and postevent factors. To organize this review, we utilize the above components of the Haddon Matrix to

	Host	Agent	Physical Environment	Social Environment
Preevent	Physical fitness Shift length Substance abuse Education Knowledge Skill proficiency Capability Risk threshold	Vehicle design Equipment design Vehicle testing Equipment testing Ergonomic considerations Vehicle maintenance Equipment maintenance	Hands-free devices Ergonomic design of vehicle interior	Public expectation for response times Call prioritization Driver training Culture of seat-belt use Emphasis on speed Emphasis on lights-and-siren use Availability (lack of) consensus on vehicle design standards Availability (lack of) driver training standards
Event	Distracted EMS driver Fatigue Seat-belt use Risk-taking behavior	Speed Lights-and-siren use Stability of vehicle in transit	Weather Agitated or violent patients Character of interior surfaces Road conditions Traffic Curious onlookers	Seat-belt use Driving habits Willingness to recognize error
Postevent	Pre-existing conditions Physical fitness	Prevention of fire risk Escapability of the cabin Crash information collection Stability of the vehicle after collision	Post hoc analysis of event Root cause analysis Availability of emergency responders (for ambulance crash)	Error recognition Error reporting Behavior change Human factor analysis

Figure 1. Haddon Matrix for emergency medical services (EMS) provider and patient safety during response and transport.

consider each of the variables that affect safety in and around an ambulance.

We describe the contents and subsequent ideas discussed and developed from a consensus conference on ambulance safety. The examples and concepts described have been identified by qualitative review of the published literature and consensus discussion with experts in the field. We identify and describe the concepts and examples of *host factors, agent factors, physical environment factors, and social environment factors*. After identifying and classifying factors relating to ambulance safety, we propose solutions to these problems. The solutions herein represent published proposals for improvement in safety, and our expert consensus developed during this conference and project. Finally, we identify limitations, areas for future research, and conclusions regarding ambulance safety.

Expert Conference

In January 2010, a two-day ambulance safety conference was held in conjunction with the annual National Association of EMS Physicians conference held in Phoenix, Arizona. Researchers, technical experts, and industry leaders provided current evidence and opinion regarding safety in and around an ambulance. The organizing committee also invited industry, community, and EMS partners from around the world to participate in the discussions. The conference was audio-taped with permission of the speakers and audience. Those recordings and the content of the speakers' presentations form the basis of the following discussion. The ideas represented are organized into headings and subheadings by the components of the Haddon Matrix, as described above. None of the ambulance safety conference speakers utilized the time dimension of the Haddon Matrix. While we think this dimension is important, we do not break down discussion into temporal components.

Host

Host Factors

Conceptualizing the EMS professional as the host in Haddon's injury matrix allows us to examine many facets of injury that occur in and around an ambulance during the care and transport of a patient. Host factors that may play an important role in ambulance safety include fitness, sleepiness, education, knowledge, skills, and capability.

The health and fitness of EMS professionals may predispose them to injury in the conduct of their duties. Wellness initiatives such as those found in the fire services are not widely embraced or enforced within EMS.[27,28] Additionally, personnel who are fit and healthy are able to recover from illness or injury more rapidly than others. The rate of substance abuse among EMS professionals is unknown but is estimated to be as high as 40% in other emergency response professions.[29] Substance abuse among EMS professionals may presage injury events, particularly among drivers of emergency vehicles.[30,31] Additionally, EMS providers work around-the-clock and often endure 12- or 24-hour shifts, with limited opportunities for meals or rest. This leads to fatigue, which plays a role in the occurrence of adverse events in EMS settings.[32–35] In medical education and in-hospital care settings, it has been found that longer work hours lead to more medical errors and adverse events as well,[36,37] information that should be considered in the design of prehospital care systems and consideration of both patient and provider safety.

Education and knowledge are also critical elements in the prevention of ambulance crashes. One study indicated that EMS personnel may not possess adequate knowledge of traffic laws pertaining to driving an ambulance with lights and siren.[38] It was noticed, however, that test scores increased when drivers had more experience and when they had taken at least one driving course. Knowledge of ergonomic principles and proper lifting techniques may also be important to prevent injury; however, there is little research exploring the impact of this type of training.

The EMS driver's skill determines, in part, both the safety of the occupants and the medical outcome of the patient, and is therefore one of the most critical elements in ambulance safety. Custalow and Gravitz's data from Denver suggest that drivers of ambulances involved in crashes have often been involved in previous ambulance crashes. Considering all the drivers involved in crashes, 49% had a history of multiple collisions in this study.[10] Kahn et al.'s 11-year analysis of a national database found that 41% of ambulance drivers had a record of prior crashes, suspensions, and/or motor vehicle citations.[4] Biggers et al. found that five drivers in their study were responsible for 88% of all injury collisions.[39] We have little data regarding driver fatigue and the work schedules of personnel involved in crashes.

Host Factor Solutions

Current occupational health literature indicates that EMS professionals suffer from a high incident rate of injury; however, there are currently no standardized methods to report the injuries of EMS providers.[3,16,40–46] This lack of standardization hinders the measurement of injuries to EMS providers, and makes it difficult to systematically evaluate and reduce such injuries. In addition, existing data are rarely shared outside of a single EMS agency or jurisdiction. Most safety decisions are made on a local level by individual agencies and not by national leadership groups. This lack of centralized organization and consensus standards makes broad policy changes difficult to achieve on a large scale. Standardized data collection regarding EMS worker injuries could allow for the development of greater research capabilities and could facilitate more rigorous scientific testing for interventions to protect prehospital professionals. This approach could also reduce cost by identifying effective processes and tools that may be used widely across systems and jurisdictions.

EMS provider injury can be reduced through focused and creative efforts as demonstrated by the work of Lavender and colleagues.[47–54] This work highlights the success that can be achieved when rigorous scientific testing is used to develop ergonomic equipment specifically designed to meet the challenges of providing patient care in the prehospital environment. Lavender et al. first utilized focus groups of firefighters and identified high self-reported rates of musculoskeletal injuries, especially during tasks working directly with patients.[48] After the focus groups, the authors conducted one-on-one interviews and broad surveys to characterize high-risk activities by level of frequency and strenuous physical exertion required.[47] They determined that carrying patients down stairs and transferring patients to a stretcher were the highest-risk behaviors EMS providers faced on a daily basis. Using this information, the researchers designed simulations of these tasks and videotaped small groups of prehospital providers completing them. They recorded complex measurements of posture, spine angles, and measured loads to calculate forces utilized during each activity.[48,49] This participatory design process yielded such diverse ideas as new handles for backboards, foot straps on backboards to prevent patients from falling off while descending stairs,[52] friction-reducing slide boards for lateral transfers,[51] specialized lifting straps and rods to facilitate better patient lifting,[50] and even motorized stretchers with special tracks designed to control the descent down stairs without heavy lifting.[47] Other creative investigators are also contributing to the field of prehospital ergonomics.[55–57]

Technology is making significant inroads into assisting drivers in carrying out their duties.[58] Notably, several investigators have explored driver monitoring and feedback systems to help change dangerous driving behavior. De Graeve et al. experimented with the installation of a driver feedback system in ambulances in Belgium.[59] The device monitors driving parameters such as harsh braking and speed and can provide feedback to the driver in real time. These authors found a modest but sustained decrease in aggressive driving patterns. Levick and Swanson examined the effect of a monitoring and feedback system on driver performance in ambulances in Little Rock, Arkansas. Seatbelt violations, in the front seats, dropped from 13,500 to 4 per month and overspeed events, defined as 74 mph during non–lights-and-siren use and 84 mph during lights-and-siren use, dropped from 550,353 to 207 violations per month. Additionally, there was a 20% savings in vehicle maintenance within a six-month period.[60] Myers et al. evaluated the effect of a driving-event monitoring system with a formal review and feedback loop in 54 rural and urban communities in Wisconsin and Minnesota.[61] Over a two-year period, events decreased significantly in these EMS agencies. Other devices are available that can alert drivers entering intersections to the presence of other vehicles, notify them when they are too close to a vehicle (to prevent a collision), and warn drivers when they are about to run off the road.[58] To date, there are no published studies evaluating the effect of these technological advances in ambulances.

Alternative Host

We must also consider the patient as a host in the Haddon Matrix because the patient's comorbid and acute medical conditions make the patient susceptible to injury or decline in health status as a result of ambulance transport or a crash. There are no available published reports of data regarding patient host factors that may contribute to or mitigate injury in a moving vehicle.

Agent

Agent Factors

As previously noted, the *agent of injury* refers to the energy exerted during the course of an injury, and may be modified to include unrestrained equipment that contributes to the injury.[26] In the context of safety in a moving vehicle, the ambulance itself is the most obvious equipment to be considered. Ambulance design and maintenance are of primary consideration, as are the use of audible and visual warning devices. The equipment within an ambulance is also important in the discussion of safety in the moving ambulance, particularly if it is not carefully secured.

Standardized testing of the crashworthiness of ambulances in the United States is not required by statute, law, or practice in the automotive industry. In an effort to understand the hazards to occupants during an ambulance crash, a few investigators have pursued crash testing of emergency vehicles.[11,62–65] Their work suggests that the rear of an ambulance is filled with danger from loose equipment, poorly designed surfaces, and poorly designed restraint systems. In comparison, European ambulances must meet standards for front, rear, side, and rollover impacts.[66] Australia has developed the only nationally approved safety standard applicable to emergency vehicles.[67–69] The United States has not adopted such requirements.

In crash tests of ambulances, Levick et al. demonstrated that a number of critical ambulance design features need to be addressed. During crashes, despite velocities and mechanisms that were survivable, unrestrained crash test dummies sustained severe injury mechanisms from "hostile interior surfaces." Levick et al. also demonstrated the propensity for severe head trauma in the occupants of ambulance rear compartments during crashes.[11,65,70] There is no epidemiologic data from which to determine the specific nature of injuries sustained in ambulance crashes.

There are currently no standardized, comprehensive, and research-based guidelines for ambulance design, manufacturing, and testing.[65] The Federal KKK-A-1822F Star-of-Life Ambulance purchase specifications are the most commonly used, but they provide limited guidelines for the safety aspects of ambulance design.[71] These guidelines rely on static rather than dynamic safety testing[65] and provide no guidelines for the use of forward-facing seats, four-point restraint systems, or other aspects of ambulance design aimed at improving the safety of existing ambulances. The ambulance standards of the Ambulance Manufacturing Division of the National Truck Equipment Association also fail to require dynamic or impact testing.[72] Additionally, Federal Motor Vehicle Safety Standards exempt ambulances 2 feet rearward of the driver, effectively disregarding, and exemplifying a lack of regulation for, the patient compartment.[65,73]

Various mechanisms for collecting information on ambulance crashes currently exist, but are limited. These include the Fatality Analysis Reporting System and the National Automotive Sampling System maintained by the National Highway Traffic Safety Administration, the CoOperative Network Call for Emergency Regional Notification maintained by the Air & Surface Transport Nurses Association, and the open-model Ambulance Crash Log held by EMSNetwork.org. Details specific to ambulance collisions, such as the presence or utility of specific safety features and their contribution to the collision or injuries sustained, are also not identified by these broad crash data–collection systems. Another limitation is that data collection is typically the duty of the state and most often relies solely on police and traffic accident reports.[19,74] Other federal data-collection systems, such as those maintained by the Federal Motor Carrier Safety Administration, a part of the U.S. Department of Transportation, provide additional models for processes that could serve to standardize incident data collection at a national level. However, at this time ambulances are exempt from federal commercial fleet safety oversight.[65]

Many vehicle characteristics contribute to ambulance safety. To avoid collisions when traveling during emergency responses, ambulances must be readily visible to other drivers and pedestrians.[75] While lights and siren are essential features of all ambulances, the use of highly visible color schemes and reflective materials is not universal. For example, high-visibility green or yellow has been suggested as providing improved visibility over other commonly used colors such as red or Omaha orange,[76] but this has not been universally adopted. Many EMS systems continue to use color designs that are not easily seen at night and do not uniquely identify ambulances.[65,75]

While exterior ambulance safety is related to crashworthiness and visibility, the interior of an ambulance is full of components that affect the safety of EMS providers and patients. The availability and use of provider and patient restraint devices are of considerable concern. While drivers of emergency vehicles use seat belts, the majority of the time, EMS providers working in the rear compartment rarely wear safety devices throughout the entire transport, particularly when actively providing patient care.[4,20,21,77] Many of the reasons for the lack of seat-belt compliance revolve around providers' perceived need to access the patient and equipment in order to continue actively performing patient care while in transit.[77]

The traditional design of an ambulance consists of a side-facing bench seat adjacent to a stretcher, a rear-facing seat at the head of the patient, and cabinetry on either side of the ambulance. Wearing a seat belt from any seating position in this configuration limits the provider's access to the patient and equipment. This traditional configuration does not take ergonomics and other human-based design aspects into consideration[65] and has been demonstrated to contribute to unsafe postures that have been associated with common occupational injuries in EMS providers.[3,57] EMS providers are also at significant risk of balance loss due to frequent changes in acceleration and direction during transport.[78–80]

The security and design of equipment commonly encountered within an ambulance can also contribute to injury. During sudden acceleration or deceleration events, equipment can become flying missiles, injuring EMS professionals and patients alike. Other than references from Levick et al. to sharp corners and "hostile interior surfaces,"[11,70] we know little about the movement of equipment during an ambulance crash. In Levick et al.'s tests of crashworthiness, the authors carefully strapped equipment in place to prevent its movement so as to study the movement and injuries of the crash dummies alone. Since equipment is frequently unrestrained and in use during ambulance transport, it is reasonable to assume that flying equipment contributes to the risk of injury to EMS personnel and patients.

Agent Factor Solutions

Rigorous standards have been developed by the Common European Community[66] and the Ambulance Restraint Standard AS/NZS in Australia and New Zealand,[67] which includes dynamic testing and the use of 50th- and 95th-percentile manikins.[81] A lack of dynamic crash testing requirements has resulted in persistent questions about the ideal drive trains and braking components for ambulances, as well as crashworthiness in front, rear, side, and rollover collisions for various models. Individual manufacturers have developed their own safety features and methods of testing ambulances, but purchasers have no comparison of the safety of ambulances and their components.[11,62,82]

If EMS professionals were able to remain in a stable, seated position for longer periods of time, this intervention could cut the risk of falls and subsequent injury significantly. Slattery and Silver suggested improving provider safety in the rear compartment of a moving ambulance by implementing policies or protocols that utilize technological advances designed to free the hands of EMS workers.[83] For example, automatic chest compression devices or mechanical ventilators are current potential solutions that could allow EMS workers to remain seated and restrained. Similar technologies exist to allow hands-free electronic communication and these could minimize movement involved with rear compartment radio use. While these strategies may be feasible for some EMS systems, Slattery and Silver recognize that this type of technology may be prohibitively expensive and may not be cost-effective for many EMS systems. Nonetheless, these costs should be weighed against potential savings in worker compensation bills or legal claims related to crash-associated injuries.[83,84]

The ergonomic principles that apply to internal ambulance design are not new concepts, but exemplify a lack of communication and collaboration among stakeholders in ambulance safety, from ergonomists and automotive engineers to federal regulators, ambulance manufacturers, and EMS agencies. In the most basic definition, ergonomics is the design of work systems around the physical and cognitive capabilities and limitations of people. Currently, ergonomic principles have not been used on a consistent basis in ambulance design.

Failure to design work systems ergonomically may lead to accidents, injuries, and increased errors by EMS providers. Much of the equipment used commonly in the rear compartment is out of reach for providers, so they must stand or bend to access blood pressure machines, cardiac monitors, sharps containers, and oxygen devices. Even reaching the patient is often difficult, with stretchers latched low to the ground. Often providers need to move between or within seats to access a patient's airway, chest, or extremities. While ambulance crashes may account for the largest proportion of fatalities in EMS, strains and sprains account for the most injuries with days away from work.[2,3] Good ergonomic design may not reduce the number of ambulance crashes, but it may reduce the number of total injuries that occur in or around the ambulance.

Physical Environment

Physical Environment Factors

To consider the physical environment factors contributing to safety in a moving ambulance, we need to evaluate driving speed, weather, and road conditions. By necessity, ambulances must be on the road in a variety of weather conditions during daytime and nighttime hours. Ambulances approaching emergency scenes often encounter numerous distractions. Such distractions include other units responding to the same scene, traffic, and curious onlookers.

There is limited information on the frequent job tasks that occur during delivery of patient care and transportation in a moving ambulance. Existing analyses have focused primarily on lifting and moving,[50–52] with some research on the ergonomics of activities inside the patient care compartment of an ambulance.[56,57,85] The physical environment within the patient compartment of an ambulance can compromise a provider's ability to safely deliver care.

Risks become apparent in the rear compartment when the environment is analyzed from an ergonomic perspective. Ferreira and Hignett observed paramedics during the course of their duties in the rear compartment of British ambulances.[56] These ergonomic specialists determined that the equipment required by paramedics to monitor and treat patients was arranged in locations convenient for storage but not convenient for access and actual use. Approximately 40% of paramedic postures were ergonomically poor and placed the paramedic at risk for injury. Eleven percent of the postures were standing in the rear compartment unrestrained. Doormaal et al. also found that during nonemergency calls, 24% of postures required corrective action, whereas during emergency calls, 56% of postures required attention.[85]

Gilad and Byran surveyed paramedics about their experiences in the rear compartment of ambulances.[57] They found that 74% of paramedics felt the position of the seating was insufficient to care for patients, 77% felt the vertical distance between the seating and the patient was excessive, and 86% felt the need to steady themselves during transport. The authors then performed an ergonomic evaluation of paramedics during their work, finding that ergonomically disadvantageous postures were frequently utilized. Gilad and Byran proposed several interesting and as-yet-untested design modifications for the rear compartment of ambulances.

Several investigators have found that the quality of cardiopulmonary resuscitation (CPR) provided during transport or simulated transport was poor.[86–89] Stapleton examined the quality of CPR performed by three paramedic CPR instructors in a moving ambulance during a 10-minute ride as compared with a mechanical device.[90] The mechanical device delivered adequate compressions 97% of the time as compared with manually delivered compressions, which were adequate only 37% of the time. Ventilations were similarly compromised. The manually triggered ventilator delivered adequate ventilations 71% of the time, mouth-to-mouth ventilation 60% of the time, and bag–valve–mask ventilation 46% of the time. It seems clear that, among these types of patients, care in the back of a moving ambulance is difficult and often poorly executed, perhaps resulting in less-than-optimal patient outcomes and threats to provider safety. Devices to automate delivery of care are on the market and feasible for prehospital use, but are not frequently used or studied and are limited to a few clinical conditions.

Physical Environment Solutions

Solutions for physical environment factors will require creative input from a variety of sources. It is difficult to change the scene of a crash, but changing the actions and responses of providers is possible. Agency policy to enforce speed limits and situational awareness at the scene of an EMS response can be changed. A concerted effort is needed to create physical environments that are designed to enhance safe working conditions and delivery of care, rather than physical environments that are designed around cost or structural concerns.

To reduce the potential for injury during patient transport, we need to develop hands-free devices to provide patient care while maintaining a seated and restrained position. Hands-free devices for communication are already on the market but not widely utilized by EMS agencies. Equipment to provide mechanical chest compressions and ventilations are also on the market. This equipment may reduce the need for providers to stand and perform tasks while the vehicle is in motion, and reduce the risk of falls and loss of balance while providing care. Given that EMS providers are at significant risk of loss of balance due to frequent changes in acceleration and direction during transport,[78,79] any intervention that allows longer time in a more stable seated position could reduce the risks of falls and subsequent injury significantly. Research to investigate the safest, most efficient method to deliver high-quality patient care in a moving ambulance must be a priority for funders.

Social Environment

Social Environment Factors

EMS professionals work in challenging environments, often under austere conditions, and pride themselves on being altruistic and selfless. This emphasis of others over self has fostered a culture that often disregards provider and bystander safety in favor of response to an emergency condition. A change in the culture surrounding EMS safety is needed. All key stakeholders should recognize that safety and emergent care are not discordant concepts.[18,91] Instead, we must realize that quality patient care can be provided in a safe and timely manner. Current safety topics that may require a cultural shift can be broken into three broad areas: vehicle use, personnel management, and behavioral response. Vehicle use incorporates ambulance response times, lights and siren use, and call prioritization. Personnel management includes seat-belt usage and driver training. Behavioral response includes the notion of speed at all costs, personal accountability, error recognition, and self-reporting.

Ambulance response times are a highly political topic. Response times are often set by local government as part of ambulance service contracts or are derived based on the geography an ambulance can cover from a fixed post. Currently, individuals living in urban environments have been conditioned to expect rapid ambulance response when EMS is activated for any reason. This has occurred despite the current evidence, which suggests that there is limited utility in a rapid EMS response for most of the patients treated by EMS.[92–94] While it is likely that response times could be safely increased for many call types, communicating to the community the reasons why these changes are taking place may be very difficult. A paradigm shift regarding ambulance response times will not be instantaneous and will require time to evolve within communities.

The responders, like those to whom they respond, also share this paradigm of speed. Currently, it is common practice to use lights and siren for even minor responses, with the perception that this will decrease response times. Common reasons for the use of lights-and-siren response include possible time savings, tradition, and even requirements by insurance companies.[75] However, few emergent conditions are truly time-dependent to an extent that would likely result in clinical benefit from a lights-and-siren response. Kupas suggests that lights-and-siren transport to the hospital should be considered a sentinel event for quality assurance reporting and should represent less than 1% of all scene-to-hospital transports.[75]

An abundance of research indicates that a cultural divide exists among EMS professionals in regard to seat-belt usage.[22,75,77] As we are members of a profession that witnesses the direct result of being unbelted in a motor vehicle crash, one would think that our frequency of seat-belt use would be high. However, literature suggests that EMS professionals often do not wear their safety belts, especially when working in the patient compartment.[20,21,77] It appears as though many EMS professionals set aside personal safety in favor of unrestricted access to the patient.

Cultural changes regarding daily vehicle operation are also much needed. Currently, there is no national standard for training EMS personnel to operate an ambulance. There are several nationally recognized operator courses such as the Emergency Vehicle Operator's Courses, but not all agencies require such training. Classroom training, driving range practice, and on-the-road assessment in the ambulance are integral parts of the emergency vehicle operator courses, yet it has not been demonstrated that these courses produce safer drivers.[17]

Behavioral response is cultivated by the safety attitudes of an organization. Often referred to as "the way we do things around here," safety culture often predicts, or dictates, individual behavior.[95] Adverse events that affect patient safety are not always attributed to vehicles; in fact, only 20% of adverse events stem from ambulance problems. Human factors contribute most to patient harm. In recognition of human limitation, it is important for organizations to adopt a safety culture. In a safety-focused organization, "there are no bad people, only bad systems."[96]

The challenge of instilling a culture of safety is not unique to EMS; in medicine, patients are frequently harmed through their exposure to health care, completely independent of their disease process.[97] Adverse events are the eighth leading cause of death in hospitals, and the emergency department is the most likely place for these adverse events to occur.[98,99] Research suggests that as many as half of all intrahospital intensive care unit (ICU) transports involve an adverse event.[97,100,101] These inhospital patients share many similarities to prehospital patients; they are being moved from one place to another, are acutely ill, and are cared for by providers of different capabilities. While few data exist to shine light on adverse events in prehospital care, aeromedical transport research has identified that serious adverse events do occur.[96,102–105] The Canadian Patient Safety Institute executed a systematic review and identified a paucity of literature examining adverse events in the prehospital setting.[18,106] Wang et al. performed a retrospective review of tort claims. They found that although vehicle collisions accounted for 37% of tort claims, the majority were due to factors other than collision: 36% patient handling, 12% clinical management, and 8% delayed responses.[107] In a prospective observational study, EMS professionals were asked to anonymously report adverse events and their causes.[108] Most adverse events were caused by a lack of available resources (27%), followed by communication problems (18%), prolonged response times (16%), resuscitation difficulties (16%), other treatment problems (10%), and equipment problems (5%). LeBlanc et al. examined the incidence of medication calculation errors among EMS professionals and found that, during observed medical simulations, errors increased when a stressor such as a panicked bystander was introduced to the scenario (43.1% vs. 57.9%).[109]

To reduce the incidence of these adverse events, qualitative research with EMS providers has been pursued. Fairbanks et al. have performed quite a bit of research in this area. They reported that EMS providers rank nonpunitive reporting systems highly in fostering a culture of self-reporting. When asked to identify the root causes of adverse events, they reported a lack of standardization between agencies and facilities, adversarial interrelationships between EMS providers and allied agency staff and hospital staff, and communication breakdown.[110] Hobgood et al. have extensively studied the self-reporting behavior of prehospital care providers.[111–113] In a 2006 convenience sample survey of providers, 55% had not reported an error in the previous year, 35% had reported one or two errors, and 9% had reported more than two errors.[113] Experienced providers were more likely than novice providers to report at least one error in the previous 12 months (30% vs. 6%).

Social Environment Solutions

The reliance on response times as a performance measure for EMS systems must be addressed. Using speed as a measure of quality has no meaning. EMS providers should be allowed to use discretion with the use of lights and siren. To do this safely, dispatch information must be accurate and informative. Certified emergency medical dispatchers utilizing a medical priority dispatching system may reduce lights-and-siren responses. Additional research into the effect of lights-and-siren use is needed to better understand the value of utilizing such risky tools.

Research has indicated that the amount of time saved by transporting patients using lights and siren is insignificant in both rural and urban settings.[114–121] Other methods for improving patient outcomes exist independent of the speed at which an ambulance travels. In a patient experiencing an acute heart attack, early activation of a cardiac catheterization laboratory using radio communication would overshadow any time savings of a lights-and-siren transport.[116,118,122,123] One potential way to decrease lights-and-siren use during transport would be the development of a set of standard protocols for the acceptable use of lights and siren during transport. Adoption of such protocols may aid the movement to change EMS culture in this area.

One method for standardizing the type of response patients receive (lights and siren or not) is the use of a call prioritization system. Several dispatch protocol systems are on the market and are used across the nation. As an example, the Medical Priority Dispatch System uses certified emergency medical dispatchers to classify medical calls into a series of priorities from which local medical control can determine an appropriate response. While some EMS agencies use some method of call prioritization, there are many who still respond to all calls with lights and siren. Current research and practice have indicated that use of these types of call prioritization systems is a safe way to determine the response priorities that patients need.[124–127] In combination with modifying response times and limiting the use of lights and siren, call prioritization may help replace the "rush" culture of EMS with a culture revolving around the safe and timely delivery of care.

Use of seat belts requires two areas of change. First, we must develop and provide ergonomically effective seating positions within the ambulance that allow EMS professionals full access to the patient and allow the providers to care for the patient while seated and restrained. Second, we must create restraint systems developed in recognition of the providers' need to move and care for a patient during transport.

Instituting policies that require entry-level providers to have some baseline driving proficiency prior to starting work may be another step to improving overall safety. It is important to remember that driving is like all other cognitive and psychomotor skills and that retraining and evaluation are necessary. Specifically, individuals who have been in an initial crash are at increased risk of a second crash.[10]After a crash may be the best time to retrain the driver to reinforce safety standards.[128] Also, drivers who fall below set standards are a specific subpopulation of individuals who may need retraining.[128] Finally, agencies should be aware that EMS drivers are more likely to have a crash when they are young or inexperienced. It is important that this group be closely monitored and risky or problem behavior appropriately identified and modified with retraining.

A culture of safety within EMS must draw from other industries that have already made great strides in improving their own safety practices.[129–138] Slattery and Silver propose the concept of a "sterile cockpit" for EMS professionals during periods of lights-and-siren driving.[83,139] The Sterile Cockpit Rule is a regulation of the Federal Aviation Authority, which mandates pilots to cease any activities not directly related to the critical phase of flight in which they are engaged. Typically this refers to takeoff and landings, although other emergency situations may be included as well. The rule was developed after a series of airline crashes found to be caused by flight crews engaging in noncritical conversations and activities during critical phases.[140,141] This concept derived from the airline industry is a no-cost change in culture that may focus drivers and passengers on potential hazards during response.

Similarly, all EMS providers should have increased "situational awareness," assisting the driver in recognizing hazards and taking individual ownership for taking actions that increase the overall safety of the emergency response. This concept, crew resource management, is also borrowed from the airline industry and is promoted within the Las Vegas EMS system.[139] Slattery presented evidence that as many as 58% of EMS professionals admit to texting or talking on a cell phone during a scene response.[139]

Both experts and the medical literature support the integration of a culture of safety into EMS practice as a critical method of reducing adverse events.[75,95,97,142–148] The integration of a culture of safety is handicapped when self-reporting behavior is squashed by punitive action or where management fails to embrace and nurture patient safety best practices. The "blame and shame" paradigm of criticizing or punishing professionals who disclose adverse events impairs our ability to recognize and remediate system-level contributors to harm and limits our ability to create solutions. As in other industries and other health care settings, hierarchical relationships between different classes of EMS providers, dispatchers, and hospital staff stymie a culture of self-reporting. We must encourage a culture of open discussion of adverse events, of continual questioning and critical self-analysis, and of cross-cultural creation of solutions. Other industries, most notably the airline industry, has demonstrated that this is possible. By developing a patient safety culture, EMS systems can become safer.[95]

The Canadian Patient Safety Institute, along with the EMS Chiefs of Canada, has taken a leading role in furthering the EMS patient safety field by forming a nine-point strategic plan.[91,106] Fostering a cultural shift towards a learning culture rather than a blame-and-shame culture is seen as the key priority to improving safety for patients, and it is expected that, in concert, provider safety will be greatly enhanced.[95] Nonpunitive reporting systems are a key to fostering this culture of safety.[96]

Many different groups are currently working to foster a culture of safety to impact not only individual behaviors, but also the way that we approach these challenges, from developing individual safety features to developing new policies for ambulance response. With this new culture of safety must also come a change in our culture of working within departmental and professional silos on each of these topics. Experts, working within their own content area whether it is EMS provider safety or automotive engineering, are making progress, but to make real lasting change, we must communicate and collaborate across silos. It is imperative that the experts from both conceptual and practical realms come together to solve the problem of ambulance safety. It will take all of us working together to make a difference.

RECOMMENDATIONS FOR THE FUTURE

With each of the elements of the Haddon Matrix having been covered, the remaining issue is how to address these concerns effectively to increase safety for EMS providers and their patients. We incorporate the existing literature and the recommendations offered by the Ambulance Safety Conference experts to make recommendations for the future.

Regulations are needed for a uniform and centralized national reporting network for all ambulance crashes, including those with and without injuries.[16,65] This would provide data for research on those aspects of vehicle design, driver behavior, and system variables that impact ambulance collisions. Components here should include consistent definitions for emergency vehicles, emergency response mode, and ambulance collisions. These regulations continue to be reliant on self-reporting. Relying on traffic or police records leads to the collection of inconsistent or limited information.

A wide variety of stakeholders must be considered and should collaborate in developing regulations for ambulance design and ambulance crash reporting. Federal, state, and local regulatory and service delivery organizations must find common ground and work effectively toward changes to improve provider and patient safety. Federal legislators will also be a key in implementing new legislation related to ambulance safety as well as state legislators, departments of transportation, and state EMS offices. EMS providers and organizations must engage and collaborate in this process. Engineering and standards partners must provide expertise on vehicle, crash, and safety characteristics. Research and policy partners will also be critical in this engagement. EMS vehicle manufacturers must be on board to translate these policies into vehicles with safety components that are proven to be effective. Only through the collaboration of these and additional stakeholders will policy and process changes be possible, which could lead to a change in the culture of ambulance safety.

Innovative equipment designed to meet some of the challenges of making ambulances safer are on the horizon and currently in use in select regions. Real-time driver monitoring and feedback systems and event data recorders (EDRs) draw from the experience of the aeromedical industry to provide information that can be used to identify hazardous behavior and adverse event characteristics. The core goals of using this equipment are to improve driver performance, reduce maintenance costs, aid in crash incident investigation, and enhance overall safety.

By providing real-time feedback or through agency review of downloadable data, ambulance drivers and their partners can learn to modify behaviors that impact safety. Through crash investigation, further delineation of exactly which behaviors are most important to modify and reinforce can also be ascertained. While EDRs are expensive to purchase for a fleet, they lower maintenance costs, vehicle repair costs, and numbers of collisions, leading to lower costs from property damage, loss of productivity, and liability.[58,65] Universal adoption of these systems has the potential to increase safety and decrease costs for everyone involved in the EMS system, including drivers, providers, patients, bystanders, and insurance companies. Less-expensive technologies that also aim at increasing situational awareness are available, including internal/external cameras, internal warning lights, and two-way communication systems.

Hands-free devices improve safety in a moving ambulance and are consistent with the principle of designing a work system around the prehospital provider. Such hands-free technologies include not only radio or telephone devices, but also equipment to provide mechanical chest compressions and ventilation.[149] However, the effectiveness of individual devices for reducing injury among providers and the impact that they have on overall patient care have not been thoroughly tested. A major limitation to these new technologies is their expense and lack of cost-effectiveness for many EMS systems.[83,149] A cost–benefit analysis of effective safety measures is needed.

Other areas for improvement include increasing funding for ambulance design and safety, including research on existing systems and investigation into innovative concepts. This research should focus on taking a systems-based approach with human factors in mind as a basis for engineering. Safety standards and regulations could be developed that focus on ambulances and other emergency vehicles. These standards could draw from existing models in Europe and Australia and include independent testing of individual safety features, along with dynamic impact testing reproducing real-world conditions. As more data on individual safety features and vehicle characteristics are obtained, uniform ambulance manufacturing standards should be developed. Finally, innovative technologies, such as driver monitoring and feedback systems, have been demonstrated to improve safety and reduce costs, and should be adopted across the industry.

Prior to employment, rigorous standards should be utilized for the selection of EMS professionals. Driving and crash records with both civilian and EMS vehicles should be reviewed and driver training certificates considered. References from past employers should also be utilized. Tests and instruments designed to assess risk-taking behavior could also be incorporated into the applicant selection process. Physical health assessments should also be considered. National guidelines for hiring EMS professionals based on safe driving histories are nonexistent.[128]

Once EMS professionals employed, a driver training program should be provided.[128] A culture of safety should be encouraged from the outset[75] and employees should feel comfortable refusing to drive vehicles they believe are not roadworthy. Classroom training, driving range practice, and on-the-road assessment in the ambulance are integral parts of the Emergency Vehicle Operator's Courses.[150] Not all agencies require initial or ongoing Emergency Vehicle Operator's Course training, and research into the effectiveness of this training is lacking.[150]

Behavioral issues that require cultural change include an understanding of "due regard" for the safety of others.[128] For example, drivers need to focus on safe passage through an intersection. Stopping at every red light and visually clearing the intersection requires vehicle operators to be fully focused on the emergent response. The concept of a "sterile cockpit" and of crew resource management, adapted from the airline industry, may help reduce preventable crashes. Simple crash-reduction techniques such as safe placement of the EMS vehicle at a scene, or utilizing backup guidance with either a spotter or a camera and to watch mirrors, doors, overhead clearance, and fixed objects (e.g., poles), may improve safety. Vehicles must be maintained with a scheduled maintenance plan to ensure providers are operating and riding in a safe vehicle. EMS providers must be empowered to sideline an unsafe vehicle if they feel it is necessary at any time during their shift. The culture of safety must be embraced at every level of the organization from individual maintenance crews to the lead federal agency.

Currently, there are no national standards for mandated rest requirements between shifts, e.g., after working 24-hour shifts, working multiple shifts, or working shifts at another job. Agencies must also establish policies to deal with impaired drivers, including prescription medications, alcohol, illicit drugs, and fatigue. Finally, commonsense approaches to safety and culture change must occur. For example, if an individual has lost his or her driver's license for any reason, this must be reported to the supervisors and driving privileges must be suspended. Although rare, unlicensed driving of emergency vehicles occurs and is an indicator of disregard for the culture of safety in EMS.[128]

One of the largest barriers to safety in EMS is the culture of driving that has been embedded into the profession. The habit of responding with lights and siren for every call must be stopped. EMS professionals, national stakeholders, and the public need to be informed and understand the risks associated with emergency travel.

To reduce non–vehicle-related adverse events, organizations must foster a safety culture where nonpunitive reporting of near-misses and adverse events leads to system improvements. Consideration of human factors in the engineering of these systems is key. To further develop the body of knowledge related to prehospital patient safety, more research is needed. Funding for both research and human resource development is critical to this endeavor. Graduate studies and the pursuit of research careers should be encouraged and facilitated for those EMS providers interested in contributing to this scientific field. Finally, researchers, policymakers, funders, and administrators must pay attention to the temporal dimension of the Haddon Matrix. Currently, there is a lack of consideration for the time axis of safety during ambulance transport. It is not just the elements and events that occur during transport that lead to injury. Many predictors of injury are present in the culture, policy, and protocols of EMS operations. These elements must be taken into consideration in research and policy making.

CONCLUSION

EMS personnel encounter a hazardous and difficult work environment in a moving ambulance while providing lifesaving and life-sustaining emergency patient care. A growing body of research demonstrates that ambulance crashes are common. Deadly events may be preventable with attention to ambulance external design and to internal configuration of the rear compartment. Additionally, crashworthiness testing of ambulances may provide additional information that, if applied, can save the lives of providers and patients involved in ambulance crashes. The driver of the ambulance is critical to the safety of ambulance passengers. The use of driver monitoring and feedback systems may improve driver skill and habits, which in turn will improve ambulance safety. The rear compartment of ambulances frequently contains "hostile surfaces," ergonomically disadvantageous configurations, and poorly designed restraint systems, all of which increase the likelihood of injury and death for the occupants.

A number of groups are currently in the process of working toward some of these goals. The National Institute of Occupational Safety and Health is currently undergoing a four-year effort to provide information to aid in improving existing standards, with a focus on patient and EMS personnel safety in the patient compartment of an ambulance.[19,74] The National Fire Protection Association Technical Committee on Ambulances is also undergoing a multiyear effort to define requirements for new ambulances. The Society for Automotive Engineers is in the process of developing vehicle crashworthiness and occupant safety standards. The International Organization for Standardization and numerous other groups have efforts currently under way to improve policies and standards, but collaboration among groups and further research is needed to enhance these efforts. The National Academies Transportation Research Board has been organizing yearly summits on ambulance safety to bring these and other experts together.[65] Through these and additional avenues of interdepartmental collaboration will come an opportunity for a true systemwide impact on ambulance safety. Medical care in a moving ambulance is often less than optimal and may result in poor patient outcome or provider injury. It is extremely difficult, if not impossible, to manually perform CPR to the standard required to sustain life while standing in the back of an ambulance traveling emergently to a hospital. Addressing and solving the problem of safely providing patient care in a moving ambulance will require experts in a large and diverse community to come together to discuss and plan for the future. While there are investigators examining pieces of this puzzle, they are often working in individual silos. Collaboration, transparent interdisciplinary research, and policy teams are needed to effectively instigate change to improve the safety of EMS professionals and patients in a moving ambulance.

The following ambulance safety experts provided their knowledge and expertise at the National Association of EMS Physicians Ambulance Safety Conference in Phoenix, Arizona, January 2010:

The Scope of the Problem:

Jeffrey Runge (Chertoff Group)

The Vehicle Panel:

The Problem: Dave Bryson (National Highway Traffic Safety Administration)

The Problem: John Brophy (National Highway Traffic Safety Administration National Center for Statistics and Analysis)

The Cost: Ronald Thackery (American Medical Response)

Prevention: Doug Kupas (Geisinger Heath System)

The Future: Nadine Levick (EMS Safety Foundation)

The Driver Panel:

Prevention: Christopher Kahn (University of California–Irvine)

Prevention: David Slattery (University of Nevada)

Accountability: William Jenaway (Volunteer Firemen's Insurance)

The Future: Jerry Overton (Road Safety International)

The Provider Panel:

Epidemiology: Brian Maguire (University of Maryland)

Epidemiology: Christopher Kahn (University of California–Irvine)

Ergonomics: Stephen Lavender (Ohio State University)

Balance Loss: Michael Kurz (Virginia Commonwealth University)

Hands-Free Devices: Annemarie Silver (Zoll Medical)

The Patient Panel:

Patient Safety in EMS–Where Are We Now?: Joe Acker (Alberta Health Services)

Learning from Other Disciplines: Jeffrey Singh (University of Toronto)

Where to Focus Future Research in Patient Safety in Land EMS Services: Blair Bigham (University of Toronto)

Where to Focus Future Research in Patient Safety in Air EMS Services: Russell MacDonald (University of Toronto)

Concluding Remarks:

Where Do We Go from Here?: Dia Gainor (EMS Director, Idaho)

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