Motor Vehicle Safety: An Update for Emergency Medicine Practitioners

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Introduction

Motor vehicle crashes are a significant burden to health in the United States[1] and worldwide. Worldwide road traffic injuries disable 20-50 million persons each year with almost 1.2 million being fatally injured.[2] WHO predicts this burden will increase significantly in the next ten years especially in low-income and middle-income countries.[2] In 2006, there were nearly 6 million police reported motor vehicle crashes in the US with 1.75 million of these crashes resulting in injury.[3] Of the more than 2.6 million people injured in these crashes, 42,642 were fatal injury victims.[3] Previous estimates using 2000 data suggested that the cost of motor crashes is in excess of 230 billion dollars or 2.3 percent of the US gross national product.[4]

Emergency medicine practitioners (EP) care for many of the drivers and passengers involved in these crashes and thus need to be knowledgeable about motor vehicle crashes. This knowledge base leads beyond the clinical care of the motor vehicle crash patient in the emergency department (ED) towards prevention strategies within the community.

Motor vehicle crash prevention requires a multi-disciplinary approach and encompasses multiple factors. Understanding the many intersecting concepts can be challenging. In 1968 William Haddon, a pioneer of motor vehicle safety, put forth that to better understand the factors associated with motor vehicle crash safety it should be conceptualized in three phases – pre-crash, crash, post-crash.[5] Further refinements to this schematic have incorporated the human (driver, passengers), vector (vehicle), physical environment and socio-economic environment factors to create a twelve cell matrix (figure 1). We utilize this model to present select issues on motor vehicle safety useful to EPs. Most of these are consistent with the 4 E's – educational, environmental, enforcement, and economic model[6] of strategies for injury prevention and control.

Figure 1. Haddon matrix

	HOST	**VECTOR**	**PHYSICAL ENVIRONMENT**	**SOCIO-ECONOMIC ENVIRONMENT**
PRE-EVENT	--Alcohol use --Distracted driving --Speeding	--Anti-lock brakes system --Automatic traction control	-- Road design --Traffic calming	--Advocacy --Enforcement --DMV reporting
EVENT	--Motorcycle helmet use --Seat belt use --Child safety seat use	--Airbags --Vehicle design --Biomechanics	--Road hazards	--Motorcycle helmet laws --Seat belt laws --Child safety seat laws

POST EVENT	--Age --Physical condition	--Automatic crash notification	--Trauma care systems	--Research data --Trauma funding

Pre-Event Variables
Several pre-event variables across human, vector, physical environment and socio-economic environment impact car crashes occurrence and severity. They serve as important points for intervention and detailed study by EPs.

Alcohol use
Alcohol related crashes cost 51 billion dollars a year[4] and account for 32% of all traffic related deaths.[7] The relative risk of a motor vehicle crash for an intoxicated driver increases with increasing blood alcohol concentration (BAC) levels with it 2.69 at 0.08 BAC, 29.48 at 0.16 and 153.68 for BAC greater than 0.25.[8]

Lowering the BAC legal limit is one measure that has been found to reduce alcohol-related crash occurrences in several countries. Fell reports a 5-16% reduction in alcohol related crashes when the United States limit went from 0.10 to 0.08, a 9.4% crash reduction in Austria when their limit went from .08 to .05 and a 7.5% crash reduction in Sweden when their limit went from 0.05 to 0.02.[9] Another measure to prevent alcohol related crashes is the establishment of police regulated sobriety checkpoints which has been found to contribute to a 20% reduction in alcohol related crashes.[10] Another enforcement strategy is the suspension of the driver license, but Voas found that up to 75% of the repeated offenders may drive illegally.[11] More effective than driver license suspension is vehicle impoundment. Deyoung found a crash decrease of 37.6% in repeat offenders during the vehicle impoundment.[12] Although not impoundment, a breath alcohol ignition interlock can be employed to make it impossible to start a car without passing the alcohol breathalyzer device. Bjerre found a 60% reduction in the rate of repeat DWI and 80% reduction in police reported traffic accidents among DWI offenders during the interlock period.[13] Once the interlock is removed, Raub found that 50% of these drivers were involved in a crash or rearrested for drunk driving within three years.[14]

Educational strategies have also been utilized at both the community and individual levels. Within the emergency department, research has demonstrated a brief intervention delivered to an injured patient who has risky alcohol use can decrease future impaired driving.[15]

Distracted driving
Driver inattention is the leading cause of motor vehicle crashes. Nearly 80% of crashes and 65% of near crashes involve some form of driver inattention within three seconds of the event.[16] This same study found that reaching for a moving object increases the risk of a crash/near crash by 8.82 times, drowsy driving by 6.23 times, reading by 3.38 times, applying makeup by 3.13 times, cell phone dialing by 2.79 times, inserting/removing a CD by 2.25 times, eating by 1.57 times and talking/listening to cell phone by 1.29 times.[16]

One environmental strategy to reduce crashes from driver inattention is road rumble strips. Shoulder rumble strips decrease the off-the-road driver inattention crashes by 18-21%.[17] Centerline rumble strips on rural tow lane roads decreases opposing direction crashes by 25%.[18] Future countermeasures for driver inattention being researched include lane tracking systems, driver's eye tracking system and collision alert systems.[19] An enforcement measure that has become increasingly enacted is a ban on hand-held cell phone usage while driving. Five states, Washington, DC and the Virgin Islands prohibit hand held cell phone usage while driving with several others restricting cell phone use in some way.[20] McEvoy found that the risk of crashing with hands free phone was 3.8 and hand held phone was 4.9.[21] Although hands free lowers the risk, it does not eliminate the distraction of cell phone usage.

Speeding

The economic cost of speeding-related crashes is estimated to be 41 billion dollars a year.[22] In addition to monetary costs, speeding plays a role in 30% of all fatal crashes in part because higher crash speeds reducing the ability of vehicle restraint systems and roadways safety guardrails to protect the vehicle occupants.[22,23] According to NHTSA, speeding-related factors have been increasing on roads with speed limits of 65 mph and higher since the repeal of the national maximum speed limit of 55 in December 1995.[23] Shafi found a 13% increase in fatalities with the 65 mph speed limit and the Insurance Institute for Highway Safety found a 38% increase in fatalities with the 75 mph speed limit.[24,25] Furthermore, as road conditions worsen, speeding plays a larger role in fatal crashes. Speeding accounts for 28% of the fatal crashes on dry roads, 33% on wet roads, 51% on snow slush roads and 58% on icy roads.[22]

With higher speeds associated with higher crash fatalities, utilizing strategies to reduce the driving speed should result in fewer fatal crashes. Speeding enforced by detection devices has been introduced in the past two decades and, although requiring more rigorous studies, has resulted in a reduction of crashes, fatalities, and the proportion of vehicles speeding.[26] Kaplan found a 31% reduction in speeding vehicles in the vicinity of the patrol car even if it is unmanned.[27] Similarly, aerial enforcement of speeding limits was associated with a 22% reduction in vehicle crashes while the posting of speeding enforcement signs was associated with a 17% reduction.[28,29] Automated speed enforcement represents another effective enforcement to reduce speed related injuries and fatalities. The Cochrane systemic review found that speed cameras reduce fatal crashes from 13% to 58%, injury crashes from 7% to 30% and all crashes from 9% to 35%.[26] Similarly, intersection cameras have been introduced to record all infractions in which a driver disregards a stop sign or red light. Red light camera enforcement has moderate aggregate crash cost benefit and contributes to some decrease in injuries and crashes.[30]

Anti-lock brakes system (ABS)/Automatic traction control (ATC)

ABS is a braking system that enables the driver to maintain steering and direction while breaking suddenly, especially in wet conditions. A preliminary evaluation of the effectiveness of ABS for passenger cars found a significant decrease in involvement of passenger cars in multivehicle crashes on wet roads with a 14% decrease for nonfatal crashes and a 24% decrease for fatal crashes.[31] However, this same report found that run off road crashes increased by 19% for nonfatal crashes and 28% for fatal crashes. ATC is an optional feature of ABS for heavy commercial vehicles designed to prevent loss of traction of the wheels. ATC has the potential to improve vehicle stability and control for heavy commercial trucks on slippery surfaces at highway speeds.[32] Similarly, electronic stability control (ESC) has been found to reduce the risk of rollover in passenger cars, SUVs and vans.[33]

Road design

Road design is an important factor in driver behavior. Traffic calming strategies, such as median barrier, speed bumps, and traffic circles are frequently utilized to require drivers to reduce speed. A systematic review and meta analysis of area wide traffic calming schemes found an 11% decrease in fatal and nonfatal road traffic injuries.[34] While positive, further evaluation of these techniques and further development of additional environmental measures is warranted.

Advocacy

EPs can contribute to a positive change in the socio-economic climate of motor vehicle safety by serving as traffic safety advocates on legislative issues. EPs are in an optimal position to use facts, clinical experiences and moral suasion to persuade the community to do more to minimize motor vehicle crashes. They can educate the community, patients and their families, and policy makers on motor vehicle crash prevention. One example is with young drivers and graduate driver’s license (GDL) programs. Motor vehicle crashes are the leading cause of death among 15-20 year old drivers.[35] Also, 16 year old drivers have a crash rate that is almost ten times the rate for drivers age 30-59.[36] One effective countermeasure is GDL, which reduce crashes in novice drivers by 31% and fatal crashes by 16%.[37,38] Chen found that the most effective components of GDL were: minimum age of 15 ½ to obtain a learners permit, minimum age of 16 to obtain an intermediate license, minimum age of 17 for full licensing, minimum of 30 hours of supervised driving, nighttime driving restrictions and a restriction on carrying passengers.[38] Even when adjustments are made for experience, teen drivers are much more prone to be involved in a crash than adults.[39] Teens drive faster, overtake other vehicles with too much risk, merge too quickly, follow too closely, and violate traffic signals more often. In the first several weeks after receiving their licenses teenagers are 12 times more likely to be in a crash than otherwise.[40] GDL laws vary from state to state. However, advocating and passing stronger traffic safety laws are only part of the solution. In order for change to occur, these laws must be enforced. EPs should work with law enforcement to make traffic safety a priority and resources are allocated to allow this to happen.

Department of motor vehicle reporting

Department of motor vehicle (DMV) reporting is another pre event action for ED practitioners to utilize in many states. Reporting patients with medical conditions that pose a public danger should the patient continue to drive is mandatory in six states and permitted in 25 states.[41] The remaining states have no policy.[41] The dilemma posed by reporting is that the physician-patient relationship is undermined when confidentiality is breached and particularly when that breach will lead to loss of an essential societal privilege, driving.[41] The American Medical Association advised that "When reporting is mandatory the physician has little choice." When it is not mandatory "…If the physician fails to report, a victim of the patient's further reckless driving due to medical impairment—may hold the physician responsible for failure to report."[42] Immunity for reporting a patient is provided by law in some states. The AMA resolution also advises that "the physician must identify and document physical and mental impairments that clearly relate to the ability to drive and the driver must pose a clear risk to the public safety". The National Transportation Safety Board pointed out that alternatives must be put in place for people who cannot be permitted to drive, particularly in rural areas.[43]

Event Variables

Event variables such as motorcycle helmet use, seat belt usage, child safety seat usage, vehicle design and biomechanics also impact the motor vehicle crash severity. Like pre event variables, EPs must understand and address these factors in order to prevent and control motor vehicle morbidity.

Motorcycle helmet usage

Motorcyclists are 37 times more likely than passenger car occupants to die in a traffic crash and 8 times more likely to be injured.[44] There has been a nine year trend in increasing numbers of motorcycle fatalities.[44] NHTSA asserts that "wearing helmets is the single most important factor in surviving motorcycle crashes."[45] An unhelmeted motorcyclist is 40% more likely to suffer a fatal head injury and 15% more likely to suffer a nonfatal injury than a helmeted motorcyclist when involved in a crash.[45] The Cochrane systemic review found helmets reduced the risk of death by 42% and the risk of head injury by 69%.[46] Houston found that states with motorcycle helmet laws had a reduction in motorcyclists fatality rates of 11.1% while states that had repealed their motorcycle helmet laws had an increase in motorcyclist fatality rate of 12.2%.[47] Unfortunately, recent trends to repeal helmet legislation have led to a substantial decrease in helmet use nationally.[45] Currently, two states have no helmet requirement, 28 have a limited helmet usually for those under 18 years of age, and 20 states have a universal helmet law.[45]

Seatbelt and child safety seat usage

EPs should be well versed in their state's seat belt and child safety seat laws and promote their use. Currently, 26 states, the District of Columbia, American Samoa, Guam, the Northern Mariana Islands, Puerto Rico and the Virgin Island have enacted primary seat belt laws and 23 states have secondary laws.

New Hampshire has neither a primary or secondary seat belt law. The ability of the police force to write infractions for safety belt use has led to an 81% usage rate.[48] Mandatory seat belt laws have decreased fatal injuries by 8% and increased seat belt use by 32%.[39] Seat belt use alone saved an estimated 15,383 saves in 2006.[48]

Proper child safety seat use has been estimated to have saved over 2,100 children 4 years of age and under and reduces the risk of death by 71% for infants and 54% for children 4 years of age and under.[48] While highly effective, NHTSA reports that 73% of all child safety seats are not installed properly.[49] To address these high levels of misuse improvements have been made such as the Lower Anchors and Tethers for Children (LATCH) system that provides standard anchorages for car seats. LATCH is required on most car seats and all cars manufactured after September 1, 2002. Additionally, car seat fitting stations have been developed (locations available at http://www.nhtsa.dot.gov/cps/cpsfitting/index.cfm) where child passenger safety technicians educate the caregivers on fitting a child to a child seat and proper technique to fasten the seat to the vehicle.

EPs should also be aware that booster seats are recommended for children under 4 feet 9 inches tall and under 80 pounds. As the US population becomes more obese the height requirement will become more crucial as the safety restraint system is designed to load the skeletal system. Booster seats reduce the risk of injury among this group by 54%.[50] However, only 41% of children between 4-7 years old were observed using a booster seat.[51] This is concerning in that for those children involved in crashes that were inappropriately placed in seat belts are 3.5 times more likely to experience a significant injury and 4.5 times more likely to include a head injury.[39]

Airbags

The auto industry in conjunction with the federal government has adopted federal regulations to help mitigate the injury to an occupant in a motor vehicle crash. These mandates are known as the Federal Motor Vehicle Safety Standards. These standards are the basis for driver and passenger airbags, seatbelt systems (including seat belt pretensioners), door padding (reduction of hip injuries) and instrument panel material and properties. It is important to remember that these standards work in conjunction with one another. Airbags are supplemental restraints to seat belts and thus seatbelts are much more effective with an airbag. Each technology alone does improve occupant outcome. However, together the reduction of injury risk is much greater than each individual technology.

It is important to understand the physical forces involved with allowing an occupant to “ride down” a motor vehicle crash. If an occupant does not utilize any type of active restraint the occupant will experience 180 g’s of deceleration. By simply using a seatbelt the occupant can decrease his average deceleration by 73% (30 g’s). If an occupant utilizes both the active and passive systems available that deceleration can be reduced by 95% (9 g’s of deceleration felt by the occupant). This has greatly reduced the number of fatalities per miles driven. Although there is some risk of injury from airbag deployment (corneal abrasions, thermal and friction burns), these types of injuries are minor compared to the facial fractures, traumatic brain injuries and severe lacerations that were seen in the era before air bags and seat belt use became common. Newer technologies are now entering the fleet in the form of side airbags (preliminary studies have shown to reduce the risk of injury,[52] knee air bag technology, “rollover curtains” to help prevent unbelted occupants from being ejected from vehicle rollovers. Also, another promising technology currently under evaluation is the four-point safety belt.

Vehicle design

Determining crash worthiness[39] of new vehicles is part of the responsibilities of NHTSA which does three types of crash tests in assessing new cars: full frontal, angled side, and rollover. Specifically tested are redesigned cars with structural changes, those expected to have high sales volume, or those with improved safety equipment.[53] Four other programs crash test vehicles and report results to the public:

New Car Assessment Programs in Australia, Europe, and Japan and the Insurance Institute of Highway Safety (IIHS).[53] Televised results of the IIHS testing have not had a consistent effect on either sales or company stock prices.

Vehicles are reported to the public within particular market classes rather than across all vehicle types.[54] Vehicles are not rated in order of their absolute safety compared to others with different weights or heights. Thus the final conclusions are left to the consumer.

Another important design problem is when vehicles collide that are dissimilar in size. One may ride up on the other such as the case with an SUV or truck over a smaller car. Intrusions in these collisions can impact passengers at the head or upper chest level. Innovations such as electronic stability control to decrease rollovers, energy absorbing instrument panels, and collapsible steering columns are other examples of engineering of the car environment to control injury occurrence during a crash.

Post Event Variables

It is equally important to consider post event variables, such as automatic crash notification, trauma care systems, research data and trauma funding, when addressing motor vehicle crash prevention. These factors impact the medical care that crash victims receive which directly impacts the frequency of death and disability related to motor vehicle crashes. Furthermore, the age and physical condition of the occupant can impact post-event care and mortality.

Automatic crash notification

Recent advances in technology have allowed for a well-integrated, multi-faceted approach to motor vehicle collisions allowing for a better understanding of crash dynamics and a plan for better trauma victim care. The first step in the development of the Advanced Automatic Crash Notification (AACN) systems was the automotive black box. The black box is, in essence, a real time event data recorder (EDR), similar to the concept currently employed in commercial air travel. The first primitive devices were installed in 1974 to gather information for NHTSA about a vehicle’s operation to determine when the air bag should deploy.[55] The EDR functions by holding a time span of data (usually 5 to 20 seconds). The old data is then deleted as new data is received by the system.[55] When a crash occurs the EDR preserves the prior recorded data, specifically the 5 – 20 seconds before the crash, for possible retrieval providing a snapshot as to what happened in the moments before impact.[55] The data that is recorded has developed from information about deceleration to a plethora of information that ranges across various parameters including maximum speed, velocity change during crash, engine throttle (% full or accelerator pedal % full), whether or not the service brake is on, ignition cycle, safety belt status, whether the front air bag warning lamp is on or off, frontal air bag deployment, time to deploy in the case of a single stage air bag or time to first stage deployment in the case of a multiple deployments, and whether a complete file was recorded (yes/no).[56] It is important to note that EDRs do not record voices, pinpoint a vehicles location or identify who is driving the vehicle. As EDRs have advanced they have been connected to global positioning systems (GPS) which has added the ability to contact emergency medical services in case of an crash (should the driver request this or be non-responsive) and notify drivers of potentially dangerous mechanical problems.

The most advanced technology that exists in the market today is known as Advanced Automatic Collision Notification or Advanced Automatic Crash Notification (AACN). This system is found on a number of motor vehicles and is used primarily to alert emergency services that a car crash has occurred and to automatically summon assistance. When a crash has occurred (as determined by various sensors such as airbag deployment or seatbelt pretensioners), the AACN will initiate an emergency wireless call to a Telematics Service Provider to deliver the vehicle's GPS location.[57] Like its predecessor the EDR, the AACN can record event data, but can now also send crash related data (vehicle speed, delta velocity, number of occupants and rollover data) to the telematic service.[57] Voice communications can be established utilizing AACNs to an emergency call center and can be used to determine the quantity and type of rescue equipment that should be dispatched.[57] Utilizing AACNs will allow for information to be transmitted instantly and automatically from the scene of the crash and can be expected to enable faster and smarter emergency rescue decision-making.[57]

Crash Injury Research and Engineering Network (CIREN) has given us a better understanding of mechanisms of injury and allowed physicians to apply this information to the management of trauma patients and develop a risk profile for various injuries as it applies to individual trauma patients.[57,58] This risk profile can be used to expedite the care of trauma victims by impacting resource deployment, basic life support ambulance, extrication equipment and determining the need for air transport. The suspicion for severe injury can also help first responders to determine if they should transfer patients to community hospitals or travel directly to the nearest level I trauma center. The reality is that a wide variety of injuries that are observed in motor vehicle crashes and can be directly correlated to crash data (ie, maximum speed, change in velocity, air bag deployment etc.). As injury models become more advanced, crash data has the potential to be applied to hospital setting. For example, EPs would have advanced notification of the trauma patients' arrival and could use crash data from AACN to make critical and time saving decisions in terms of activation of trauma teams and consultation to specialized services.[57] This timely care would help our medical system optimize care for trauma victims. Currently ACEP supports the development and implementation of programs, policies, legislation, and regulations that promote the use of AACNs and intelligent transportation systems.[57]

Research data

With the passage of the Highway Safety Act in 1966, NHTSA was assigned the responsibility of conducting vehicle safety research and establishing motor vehicle safety standards.[40] NHTSA established national surveillance systems. The Fatality Analysis Reporting System created a census of motor vehicle crash deaths and their associated characteristics. The National Automotive Sampling Systems directs research involving links between crashes and details of vehicle design, particular road conditions, the behavior of drivers, and the injuries that occur. The safety changes mandated by NHTSA were developed in the laboratories and then introduced into the nation's vehicle fleet. More field exposure led back to more laboratory work and changes in safety mandated.[40]

Research is carried out and data generated (since 1972) by NHTSA's Special Crash Investigations program that investigates crashes of particular interest such as those involving school buses, new technologies, safety defects, alternative fuel vehicles or injuries from airbags.[59] The success of the SCI program relies on receiving notification by interested parties such as police, EMS or EPs of the occurrence of events that fit SCI's mission. As McKay points out it is only recently that EPs have had access to the specific injury and severity implications of particular crashes[60] and that information was generated by SCI type investigations and data.

Older Drivers

In contrast to younger drivers, those age 65 and older have the lowest frequency of alcohol related crashes, have higher seatbelt use, and more commonly have daytime and weekday crashes.[61] This group has low occurrence crash rates per capita but have increased crashes per mile travel starting at age 70 and increasing significantly after age 80.[62] Co-morbid illnesses as well as age related decline in physiological function can potentially increase the risk for a MVC occurring and contribute to subsequent MVC morbidity and mortality in this group.[63] In 2004, there were 3,355 MVC occupant fatalities older than age 65 with an additional 177,000 nonfatal injuries in that same age group during 2005.[64] EPs need to recognize that minimal physiological reserves may cause even minimal injury to be life threatening and post crash care of the elderly trauma patient is complex and time sensitive.[63]

Trauma care systems

Over the last three decades trauma care systems have developed into a continuum of care approach consisting of injury prevention, rapid EMS response, on site emergency medical care, transport to a trauma care facility, emergency department treatment, acute hospital care and rehabilitation services.[65] This model focuses on the health of the entire population and the care of all trauma patients as opposed to only those who are critically injured. EPs play an important role in all phases of the trauma care system and must continue to provide direction to best serve its population's needs.

Funding trauma care requires the best use of available resources in order to cope with a constant and inevitable problem. EMS systems have adapted to caring for trauma patients and work within systems where trauma centers receive severe or specific trauma patients preferentially. Trauma systems often overlap state boundaries which can magnify problems of financial support and organization. Algorithms to select suitable patients and agreements between hospitals are needed to ensure transport without delay. Trauma care and trauma center funding are consistently inadequate because they care for a disproportionate number of economically disadvantaged people, are particularly susceptible to non-coverage decisions, and receive poor reimbursement from Medicaid.[66] The large and complex staff required by trauma centers is increasingly difficult to sustain. According to the 2003 report of the National Foundation for Trauma Care (NFTC), the total trauma center costs are 10.1 billion per year and losses 1 billion.[66] This figure does not include physician losses for treatment of the uninsured. Closure of trauma centers shifts the problems back to community hospitals that largely lack the staff or expertise to care for them.[67]

Conclusion

Injury prevention and control from motor vehicle crashes is a complex issue that can have effective strategies at different stages of the event. EPs can assume an important role in motor vehicle safety to prevent future motor vehicle related injury and death.

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