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- Strengthening Trauma Systems in Developing Countries
- The Essential Trauma Care Project
- Capacity Building for Injury Control
- Crash Injury Research and Engineering Network (CIREN)

AWARDS

University of Washington Outstanding Public Service Award

Ruth B. Sauber Distinguished Medical Alumni Lectureship

- Brown University Medical School Commencement

FUNDING

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Centers for Disease Control

- National Center for Injury Prevention and Control

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National Institutes of Health

- Fogarty International Center

The global burden of injuries is enormous, but has often been overlooked in attempts to improve health. There is a tendency among governments and societies in every country to consider injuries as bad luck and as unavoidable. However, much can be done to decrease the burden of injury by addressing the spectrum of injury control, including surveillance and research, injury prevention, and trauma care. Organized, scientifically based efforts can be applied at all points along this spectrum. Much remains to be done in high-income countries. However, attention is especially needed in less developed countries, where injury rates are higher, where minimal injury control activities have thus far been undertaken, and where the majority of the world's people live. My work, collaboratively with many people at work in their own home countries, has sought to address the spectrum of injury control activities globally.

In all societies, the leading cause of death was once infectious diseases; however, in developed countries, this pattern has changed over the past two centuries, with decreases in infectious diseases and increases in life expectancy. Unfortunately, some of these gains were offset by increases in other diseases, including chronic diseases and injury. Today, injury is the leading cause of years of life lost in almost every developed country.

Similar trends are underway in today's less developed countries. In middle-income countries, as in East Asia and Latin America, injury has become a leading cause of years of life lost. In low-income countries, such as in South Asia and Africa, infectious diseases continue to predominate because of their continued high toll in younger children and because of HIV/AIDS. However, even in these locations, injury is usually one of the leading causes of death among older children and working age adults.

In many developed countries, injury mortality rates have fallen in recent decades, as a result of both improved prevention efforts and improved trauma treatment capabilities. Such well-organized approaches to prevention and treatment have not been carried out in less developed countries. Moreover, basic information about the incidence, mechanisms, and causes of injury in such locations is lacking.

I and Co-workers from several countries have helped to address these concerns by working to improve the spectrum of trauma system activities (Figure 1):

1. Surveillance and research on the basic epidemiology of injury.
2. Injury Prevention.
3. Prehospital Care.
4. Hospital Based Trauma Care.

We have worked on these activities in several developing countries, including Ghana, Mexico, and Vietnam. During the conduct of this work, the

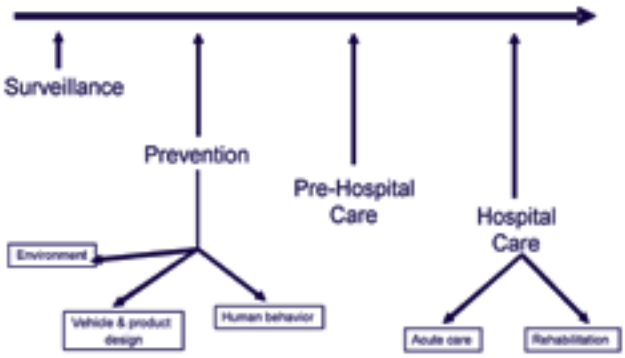

FIGURE 1. Spectrum of Injury Control

UW Department of Surgery has served as my home base. The advice and expertise of colleagues in the Department and at the Harborview Injury Prevention and Research Center has also represented a valuable resource for my work.

Strengthening Trauma Systems in Developing Countries

Surveillance and research on the basic epidemiology of injuries in developing countries

In developed countries, the usual sources of data on the incidence and consequences of injury include vital statistics registries, police accident reports and health care records. In many less developed countries, these sources are inadequate. Many or most deaths are not reported to the government. Many injured persons may never receive formal medical care, making health care records an incomplete source of data as well.

To better ascertain the incidence and consequences of injury in Ghana, co-investigators at the University of Science and Technology in Kumasi and I undertook a community-based survey of injuries in this country. Using a defined random sampling strategy, known as two-stage cluster sampling with probability proportional to size, a denominator of 21,105 persons living in 432 separate urban (city of Kumasi) and rural (Brong-Ahafo region) sites were selected.

Through direct household visits and interviews, we sought information on any injury that had resulted in one or more days of lost activity during the prior year (including fatalities). A total of 1,597 injuries were reported and analyzed. Information was obtained on the mechanism, specific body part injured, type of medical care obtained, cost of treatment, and outcome of injury, including length of disability. Information was also obtained on the economic consequences of the injury to the family of the victim.

In the urban area, the major causes of injury included falls, accidental lacerations, and transport related injuries. However, transport related injuries were more severe than the other causes, as indicated by a longer mean period of disability (64 days per injury), compared to all other injuries (37 days per injury). In the urban area, 38% of injured persons received treatment at a hospital (either emergency room visits or inpatient admissions); 30% received treatment at a government or private clinic, and 32% received no formal medical treatment.

In the rural area, the major causes of injury included agricultural injuries (30% of all injuries), falls, and transport related injuries. Compared with the urban area, significantly fewer injured persons received any type of formal medical care. Only 20% of injured persons received hospital based treatment; 31% received treatment at one of the network of non-physician staffed primary health care clinics; and nearly half (49%) of all injured persons in the rural area received no formal medical care.

Detailed information on the characteristics and outcomes of the transport related injuries has been shared with the road safety officials in Ghana. Information on health service utilization patterns has been shared with the Ministry of Health of Ghana. Data from this survey have been the basis for multiple publications on mechanisms and causes of injury, pediatric injuries, injury related disability, economic consequences of injury, trauma treatment, and epidemiologic methodology.

The data from this survey have also been useful for efforts to improve the existing information sources for trauma in Ghana. For example, a comparison of the incidence rates of pedestrian injuries in the city of Kumasi as derived from the survey with the incidence rates as derived from police reports showed that only about 10% of actual injuries were being recorded in police records. These data have prompted efforts to improve the existing information sources.

In addition to the above survey, we have undertaken research regarding trauma mortality patterns in developing countries. The goals of this study were to provide information that would help with decisions regarding trauma system development in developing countries. In developing a trauma system, decisions must be made as to the extent to which limited resources should be allocated to injury prevention programs, prehospital care, emergency room care, or other aspects of hospital based care. Hence, there is a need to know where in a nation's trauma system the greatest mortality lies.

Assessment of where the greatest improvements are to be made could be assisted by comparing such mortality patterns to those of an industrialized nation with a well-developed trauma system. In our study, we compared the trauma mortality patterns in three cities in countries at different economic levels: Seattle, WA, USA (industrialized country), Monterrey, Mexico (middle income country), and Kumasi, Ghana (low income country).

In Ghana as in many low-income countries, there is no formal emergency medical system (EMS). Ill or injured persons are usually brought to the hospital by relatives, using whatever type of transportation is available.

The main finding of this study was that with decreased socio-economic status, the overall rate of death among seriously injured patients increased, from 35% in Seattle, to 55% in Monterrey, Mexico to 63% in Kumasi, Ghana. This was, of course, not unexpected. What was somewhat surprising however was the way in which this happened. The majority of the changes in mortality between the various cities were accounted for by changes in deaths in the field (e.g., the prehospital setting). The proportion of deaths occurring in the field increased with decreasing socio-economic status, from 59% in Seattle, to 72% in Monterrey, to 81% in Kumasi. The study pointed out the importance of injury prevention efforts and prehospital care in the setting of developing countries.

Injury prevention

We have carried out research on factors contributing to injuries in Ghana in collaboration with others involved in road safety in that country, including the National Road Safety Committee, the Building and Road Research Institute, the Motor Traffic Unit of the Ghana Police, and the Ghana Police Hospital.

One study involved a random roadside breathalyzer study to assess the prevalence of drunk driving. This used methodology similar to that developed by the National Highway Traffic Safety Administration (NHTSA) in the United States. A total of 722 drivers were randomly tested on the major roads leading into the capital city of Accra, Ghana. A total of 149 (21%) of these were positive for any level of blood alcohol. Furthermore, 53 (7.3%) had blood alcohol concentration of 80 mg/dl or higher, indicating alcohol impaired driving. This prevalence of alcohol impaired driving is higher than that reported by similar methodology in developed countries (0.4 - 3.4%). It is notable that 3.7% of bus drivers and 8.0% of truck drivers had blood alcohol concentrations of 80 mg/dl or higher.

These data indicate that alcohol impaired driving is likely to be a major contributor to motor vehicle crashes in this country. Data from this study have been used by the National Road Safety Committee in its educational campaigns and have been presented to the Ghanaian Parliament in efforts to stimulate updating of Ghana's drunk driving laws.

In Mexico, injury prevention work has involved a collaborative effort of the Harborview Injury Prevention and Research Center (HIPRC) and several local institutions in the city of Monterrey, Nuevo Leon. These include the Hospital San Jose and the TEC de Monterrey School of Medicine. As part of these efforts, we have developed a program providing injury prevention counseling for parents. This focuses on improving parents' knowledge and practices of childhood safety in the Mexican environment. It has involved adaptation of existing educational materials developed by the American Academy of Pediatrics. Thus far we have carried out pilot work in this and have put on educational seminars that have had the participation of nearly 3000 parents in the Monterrey area.

Prehospital care

My efforts in the development of prehospital care capabilities in developing countries have involved Ghana, Mexico, and Vietnam.

In Ghana as in many low-income countries, there is no formal emergency medical system (EMS). Ill or injured persons are usually brought to the hospital by relatives, using whatever type of transportation is available. In a review of the mode of transport for injured persons treated at the main hospital in Kumasi (the Komfo Anokye Teaching Hospital), the great majority (70%) were brought in by some form of commercial transportation (taxis or buses); 22% were brought in by a private vehicle; 5% were brought in by the police; and only 3% were brought in by an ambulance. All of the latter were transferred from a smaller rural hospital and a hospital ambulance was used for the transfer.

Currently, efforts to institute a formal prehospital system include plans to place ambulances along the major inter-urban roads and to build up the capability of groups such as the Red Cross and the Fire Service.

Plans for EMS development are hampered by the paucity of telephones and other telecommunications in the country. Hence, current efforts also include building upon the foundation of what prehospital care does exist; namely the commercial drivers who bring in the majority of injured persons.

I am involved with pilot training programs that are being conducted through the Kwame Nkrumah University of Science and Technology and the Ghana Private Road Transport Union, to which most commercial drivers belong. These training programs are evaluating the educational background of commercial drivers and their experience with transporting injured persons, as well as providing them with basic first aid instruction. Emphasis has been on hands-on experiences through practical drills, rather than didactic lectures and written materials (Figure 2). Approximately 400 drivers have been given first aid instruction as part of this program.

FIGURE 2. Scene from first-aid training course for commercial drivers in Ghana. Extrication is practiced using previously crashed vehicle. Rubber gloves used for universal precautions.

As part of the research and development aspects of this program, we have interviewed 71 drivers one year after having taken the course. Before the course, few drivers provided any type of first aid to injured persons they transported. After the course, 61% of drivers indicated they had provided first aid during the interval year. Improvements included: airway management (2% before vs. 21% after*), bleeding control (4% vs. 25%*), splint application (1% vs. 10%*), and triage (7% vs. 21%*) (*$p < 0.05$). The course has cost $4 per driver trained.

In Mexico, as in many other middle-income countries, there are usually basic ambulance services, at least in the urban areas. My Mexican colleagues and I have been involved in ongoing efforts to improve the ambulance systems in the Monterrey metropolitan area over the past eight years. Efforts to upgrade this EMS there have included introduction of the Prehospital Trauma Life Support course (PHTLS). Introduced in 1994 for paramedics in the Green Cross ambulance service, this course has been conducted annually since that time.

In our evaluation of this program, we documented an improvement in both the process and outcome of prehospital trauma care after the PHTLS course. Airway maneuvers for patients in respiratory distress increased from 18% before the course to 43% after ($p < 0.05$). IV fluids for patients with BP < 100 increased from 44% to 81% ($p < 0.05$). En route mortality declined from 8.2% to 4.7% ($p < 0.05$). Regular PHTLS courses have cost $2600 per year (0.5% of the EMS budget). Hence, the improvements in both Ghana (a low income country) and Mexico (a middle income country) have been low cost and sustainable within the context of the local economies.

We are currently working on a project funded by the Medic One Foundation in Seattle to further the EMS development work in Mexico. This project builds upon the foundation that was started with the PHTLS project by specifically addressing increased training for advanced airway maneuvers, including endotracheal intubation.

We have also recently embarked on a program to conduct similar EMS development in Vietnam. In particular, we received a grant from USAID to establish a link between the world renowned Medic One program in Seattle and the Hanoi Emergency Transport Center. This center contains some highly motivated individuals. However, it is still at a rudimentary level and is estimated to meet only 20% of the need for EMS in the city. The program provided upgraded training for prehospital trauma care for ambulance personnel in Hanoi. This was done through exchanges of personnel between the two cities. Of special note is the fact that this was one of the first times that USAID has funded an EMS or trauma related project in a developing country. This recently completed (2002) pilot project has now been expanded to encompass 3 other Vietnamese cities (Haiphong, Danang, Khan Hoa). In July–August, 2003, 12 doctors from these cities visited Seattle for 2 weeks each. They participated in a project in a specially designed course to introduce them to the EMS and trauma care systems of Seattle and Washington State. This included lectures, practical sessions, and

rotations in the ED at Harborview and on the ambulances of Medic One. Following this, several people from UW and Medic One visited Vietnam and participated in training programs for over 100 doctors in the ambulance systems and EDs of the above noted cities in Vietnam. They helped to train a group of Vietnamese trainers who have provided similar "roll out" training to over 500 other doctors and nurses throughout that country.

As part of this ongoing work, in February, 2004, a delegation of health care leaders from Vietnam visited Seattle. These included representatives of the national Ministry of Health, as well as the heads of the Provincial Health Departments from Hanoi, Da Nang, and Khanh Hoa. They visited Medic One, Harborview Medical Center, the State Department of Health in Olympia, and a rural trauma system on Whidbey Island. The purpose of their visit was to see how Washington state organizes and provides trauma care, both prehospital and hospital-based.

Hospital based care

Experience with the Advanced Trauma Life Support Course (ATLS) of the American College of Surgeons has shown that using a structured educational approach, with well-planned teaching materials and evaluation of the course's effectiveness, can improve the process and outcome of trauma care in the U.S. and in developing nations with higher economic status, such as Trinidad.

However, in nations at the lower end of the economic spectrum, such as Ghana, facilities needed to implement the ATLS guidelines (including CAT scans and consultations with neuro- and general surgeons) are extremely limited. In rural areas, hospitals are staffed almost exclusively by general practitioners. Opportunities to refer patients are limited by poor roads and financial restrictions. Hence, training in this setting needs to be expanded beyond the early resuscitation and diagnostic work-up of the "Golden Hour" to include definitive treatment which general practitioners might be expected to perform in isolated rural hospitals. The experience of the ATLS program in the U.S. indicates that a similar approach, oriented for the particular circumstances of developing nations, could improve trauma care in these locations.

During the past eight years, in collaboration with the Department of Surgery at the University of Science and Technology in Kumasi, I have conducted several postgraduate lecture series on trauma management. These have formed the basis for the development of a more organized, standardized continuing medical education (CME) course. The material in these lectures has been updated based on surveys conducted in rural hospitals to ascertain general practitioners' needs and desires for CME. Evaluation of the effectiveness of the course has been conducted, including comparison of pre-course and post-course test results and interviews with course participants one year afterwards to assess how the course affected their practice of trauma care in rural hospitals. Results of this evaluation have identified problems that need to be corrected, as well as strengths that should be built upon in this course. It thus provides assistance to those developing similar educational programs in other African and other developing countries.

The Essential Trauma Care Project

The above sections give some indication of successful pilot projects in several countries. Many individuals from throughout the world have similar success stories to tell. The question then becomes how to take these lessons and make more progress, systematically and globally, in improving trauma care. A variety of "weak links" in the chain of trauma care need to be addressed: human resources (training, staffing); physical resources (equipment, supplies, and infrastructure); and organization & administration. In so doing we can build upon the experience gained by the WHO and others in international health. Working within the same tight financial constraints, these organizations have made considerable progress in several disease entities by developing the concept of "essential services." These are services that are highly effective, low cost, and which should realistically be available to most members of a given population.

Several programs have developed, refined, and promulgated such essential services, including the Expanded Program on Immunizations, the Essential Drug List, and the Safe Motherhood Initiative. I, and others working in trauma, feel that it is time for a similar approach to trauma care. In this regard the International Society of Surgery, through its trauma section (International Association for Trauma and Surgical Intensive Care – IATSIC) in 2001 created a "Working Group for Essential Trauma Care," with myself as chair, to specifically address this issue.

We feel that we have made some progress in this endeavor. We have formed a partnership with the World Health Organization's Injuries and Violence Prevention Department in Geneva. The two groups have worked together for the past three years. This

has entailed mostly long distance communication. In addition, there was a meeting of the two groups in Geneva in June 2002 for the "Consultation Meeting to Develop an Essential Trauma Care Programme." This involved trauma care clinicians from at least 2 countries on each continent. Through that meeting and its follow up, we have refined a list of 260 essential items of human and physical resources that we feel should be in place in the range of health facilities throughout the world. These are incorporated in a document entitled "Guidelines for Essential Trauma Care," which was published in June 2004, as a joint publication of the WHO and the International Society of Surgery. This publication is intended to serve as:

1. Part science, in that it includes a list of the items of trauma care that a panel of experts has evaluated as the most cost effective.
2. Part planning guide to assist clinicians, hospital administrators, and planners in ministries of health globally in their efforts to strengthen trauma care in their own countries.
3. Part advocacy tool, in that the Guidelines contain a delineation of the trauma care services that the WHO and the International Society of Surgery have endorsed as "Essential" and which can realistically be assured to virtually every injured person worldwide, even in the poorest countries.

A sample of some of the elements contained in the Guidelines is shown in a sample table (Figure 3).

The Guidelines have gone through a rigorous review process, with input from over 30 individuals from 20 countries. These have included people reviewing the document as individuals and also as representative of over 10 other professional organizations, such as international societies of neurosurgery and orthopedics.

	BASIC #	GP #	SPECIALIST #	TERTIARY #
Airway Skills				
Assessment of airway compromise	E	E	E	E
Manual manoeuvres (chin lift, jaw thrust, recovery position, etc)	E	E	E	E
Use of suction	D	E	E	E
Use of bag valve mask	D	E	E	E
Endotracheal intubation	D	D	E	E
Cricothyroidotomy	D	D	E	E
Airway Equipment				
Oral airway	D	E	E	E
Suction device (foot pump powered at least) and associated tubing and catheters	D	E	E	E
Bag valve mask	D	E	E	E
Laryngoscope	D	D	E	E
Endotracheal tubes	D	D	E	E
Magill forceps	D	D	E	E
Other advanced airway equipment		D	D	D

**Basic:** Outpatient clinic, often non-doctor staffed.
GP: General Practitioner staffed hospitals.
Specialist: Specialist staffed hospital, usually having a general surgeon and possibly other specialities.
Tertiary: Tertiary care hospitals, often university hospitals; wide range of specialists.
E: Essential; **D:** Desirable

FIGURE 3. Example of Essential Trauma Care Resource Matrix. **This example is for the Skills and Equipment for management of Airway obstruction in injured patients. Thirteen other matrices cover the spectrum of trauma care, including initial resuscitation, definitive acute care, and rehabilitation.**

Source: Mock C; Lormand JD; Goosen J; Joshipura M; Peden M. *Guidelines for Essential Trauma Care.* Geneva: World Health Organization, 2004.

The real test of the utility of these Guidelines is what they can accomplish on the ground in improving care of injured patients in individual countries. The authors of the Guidelines view subsequent work as a collaborative process, involving national ministries of health, country offices of the WHO, professional societies, and other stakeholders. In this regard some progress has already been made. For example:

1. The 260 elements contained in the Guidelines have served as the basis for needs assessments of the facilities that provide trauma care in four countries: India, Ghana, Vietnam, and Mexico.
2. The Guidelines have served as a focus for trauma care stakeholders' meetings in all of the above 4 countries and Sri Lanka. At these meetings, participants included professional societies that deal with trauma care, ministries of health, WHO country offices, non-government organizations, and others. At all of the meetings, the Essential Trauma Care resource guidelines were adapted to local circumstances and policy recommendations/ implementation strategies were derived. Most participants felt that these meetings constituted the highest governmental attention to trauma care yet.

Capacity Building for Injury Control

All of the above work, in both prevention and treatment, demands the expertise of trained personnel from a variety of different fields: for example, epidemiologists who can handle injury data in the development of injury surveillance systems; psychologists, media experts, and public health personnel who can develop social marketing strategies to effectively improve safety related behavior; medical personnel who can undertake outcomes research and who can effect changes in trauma system design based on such research. Perhaps one of the most important things that workers from developed countries can do in assisting developing countries is to increase and strengthen such local expertise. Along with others at the HIPRC, I have been undertaking two programs for the development of local expertise in injury prevention and control, in Mexico and Vietnam.

In Mexico, we have developed a training course in injury prevention work for health care professionals. The course has now been given three times in Monterrey over the past four years. Around 150 persons, including doctors, nurses, public health professionals, teachers, and others have taken the course. We are in the process of undertaking further research and development of this course and hope to eventually export it to other areas of Mexico and other countries in Latin America.

In Vietnam, similar work is underway. The HIPRC has entered into a project in partnership with the Hanoi School of Public Health to design a program to improve injury prevention and control training and capabilities throughout Vietnam. This program has been generously funded by Atlantic Philanthropies. Through this program we have undertaken exchanges of faculty between our two institutions. Several Hanoi School of Public Health faculty have taken short courses on injury control at UW. Likewise, through this project, the Hanoi School of Public Health and UW have put on 3 major, nationwide injury control courses during 2003–2005 in Hanoi. Each lasted 2 weeks and was attended by professionals active with injury control in institutions and provincial health departments throughout Vietnam. The first graduate student from this program, a junior faculty member at the Hanoi School of Public Health, is now enrolled at UW in the MPH (Epidemiology) program.

The above injury control capacity building has now been extended to Ghana, through a recent grant from the Fogarty International Center of the NIH. Through this grant, we are planning for similar nationwide injury courses in Ghana, as well as graduate students and other trainees to work on injury control research.

Crash injury research and engineering network (CIREN)

In addition to my work in less developed countries, I am active in research on injury prevention in the U.S. Harborview Medical Center and its associated HIPRC are part of a network organized by NHTSA that includes six other trauma centers nationwide. At each center, persons injured in motor vehicle crashes are identified. A crash investigator examines the involved vehicles for crash deformation patterns (Figure 4). The automotive findings are correlated with the patient's injuries, and hypotheses are generated regarding the biomechanical etiology of the injuries. Data from this process are fed back to NHTSA to help with the development of safety regulations and to the automobile manufacturers to help with safety engineering design.

In collaboration with the NHTSA, our center (HIPRC) has investigated several issues pertinent to vehicle safety design and related regulations. We have investigated biomechanical thresholds for femur fracture and shown that, on average, femurs tend to fracture at lower energy loading thresholds than previously suspected from cadaver tests. This has

FIGURE 4. Seattle CIREN (Crash Injury Research and Engineering Network) site crash investigator examines crashed vehicle for clues as to causes of injuries to occupants.

implications for the crash test standards that are currently used for frontal impact.

We have also investigated the effects of varying body sizes and found an increased risk of death and serious injury to larger occupants. This has implications for safety design, as most crash testing has been done using dummies of 70 kg size. There has been a push lately for more testing using small size dummies, to better account for the crash biomechanics of smaller size women and children. However, our research has shown that more attention may need to be given to larger size occupants as well.

We have investigated the effectiveness of different seatbelt systems and found that minimal protection was afforded by using a shoulder harness alone, without the associated lap belt. This is an issue, as many people assume that an automatic shoulder harness is protecting them and do not bother to buckle up their lap belt as well.

We have looked at the veracity of the safety ratings provided by the New Car Assessment Program (NCAP) of NHTSA. NCAP rates vehicles on their safety based on the forces transmitted to dummies in standardized crash tests. These forces are compared with the estimated thresholds for major head and torso injuries, as derived from cadaver tests. Assessment of these thresholds in real world crashes has been infrequent. Utilizing data from the CIREN project, we have determined that the relationship between forces in vehicle crashes and injury thresholds are more complex than initially appreciated. It appears that the likelihood of head injury has been overestimated for some vehicles, especially those that appeared most unsafe and had the highest forces to the head during standardized crash tests. However, the likelihood of head injury has been underestimated for some vehicles, especially those that appeared the most safe on crash tests. Such information is being fed back to NHTSA and its NCAP.

Another timely topic of crash worthiness research concerns the effects of vehicle mismatch. Such mismatch occurs when different types of vehicle collide. Most notably are the increased risks to occupants in passenger vehicles when they are struck by larger and higher light truck vehicles, such as sport utility vehicles and pickup trucks. Research by the Seattle CIREN team has identified patterns of injury to occupants of passenger vehicles, such as increased risk of head and chest injuries, when light truck vehicles strike the sides of passenger vehicles. This is primarily caused by intrusion of the door panel above the reinforcing bars that are placed in the doors to protect occupants against collision from other passenger vehicles. These sidebars were mandated by federal motor vehicles safety standards. They have been very effective at decreasing the rate of serious injury from passenger vehicles striking other passenger vehicles. However, the higher bumpers and increased mass of light-truck-vehicles overcomes this protection. This is especially significant given the growing number of light truck vehicles in the US vehicle fleet. Similar findings pertain to frontal collisions. These findings have been fed back to NHTSA and have been useful in that agency's efforts to update motor vehicle safety standards to improve side impact protection for passenger vehicles and to make light truck vehicle front ends less dangerous.

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**Indicates a student, resident, or fellow writing on a project for which Dr. Mock was his/her primary supervisor.*

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