CIREN

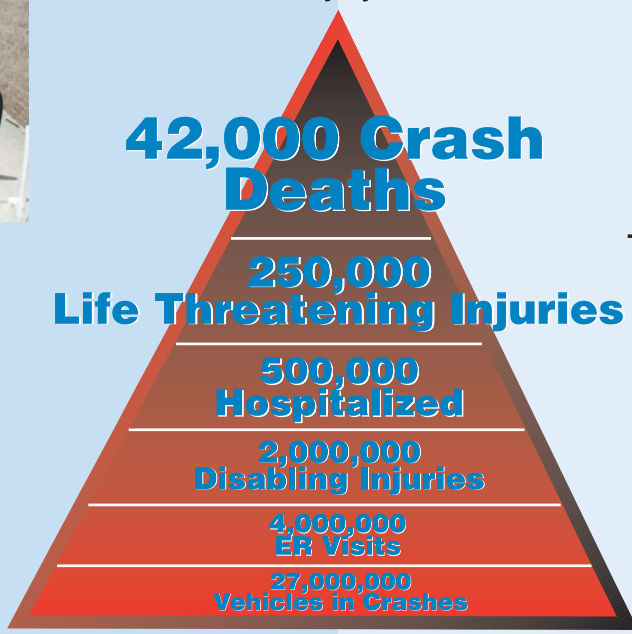
Crash Injury Research and Engineering Network

Program Report

Engineering Prevention

Medical Treatment

Serious Injury Crashes



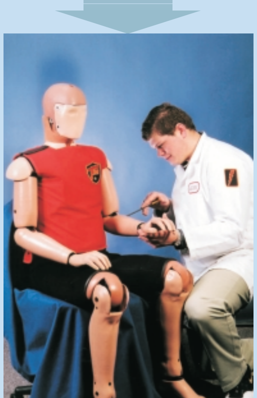
Crash Injury Costs Incurred Each Year

$100 Billion in Economic Costs

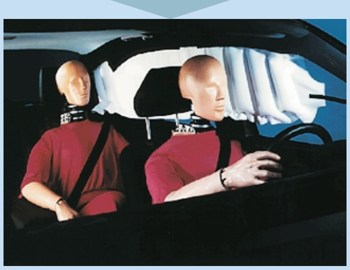
$350 Billion in Comprehensive Costs

(including costs for pain and suffering)

Crash Investigations



Smarter Crash Test Dummies



Safer Cars

Transports to Trauma Centers

Better Medical Treatments

People Saved

Foreword

by

Jeffrey W. Runge, M.D., NHTSA Administrator

As an emergency physician I personally have learned from CIREN research. I have used the life-saving techniques developed by CIREN for the diagnosis of liver injuries in crashes with 2-point belts. Furthermore, I have been able to teach better emergency care for crash victims because of CIREN findings.

The medical and engineering research efforts of CIREN form a valuable program of the National Highway Traffic Safety Administration (NHTSA). CIREN has forged powerful teams of medical researchers and safety engineers from NHTSA, universities, and the automotive industry. These teams are performing leading edge research on serious injuries in real-world crashes to advance safety.

The crash injury research contributions of the CIREN centers that are noted in this report include many findings that currently are in various stages of development, testing, and evaluation. As these findings are applied over time, the safety benefits of this basic research will become a reality and result in a Safer America.

CIREN researchers have produced more than 100 scientific publications based on research on more than 1,000 crash injured people. But, the past accomplishments of CIREN are simply a prologue to its future contributions. I can attest to this for several reasons:

- The nation has a great and urgent need to reduce the toll of nearly 42,000 crash deaths, half of which do not receive medical care at a hospital, and more than 3 million people suffering injuries in crashes that result in economic costs to the nation of $100 billion each year.
- The opportunities for CIREN contributions to advance safety are growing each year as the researchers at each center develop a greater level of understanding of opportunities to prevent and treat crash injuries.
- The collaboration of NHTSA, CIREN, and automotive industry researchers continues to grow.
- The opportunity for advancing safety is also growing as the Centers now engage in multi-center research using networked data.

This CIREN Program report highlights cumulative contributions of the center researchers to advance the prevention and treatment of crash injuries. But, the nation's need for improvements in safety demands that we not rest on our laurels. We must move forward to produce further medical and engineering advances in automotive safety.

Physicians and engineers are on the threshold of using new technologies to apply information from crash sensors to achieve faster and smarter emergency medical treatment of crash victims. We are working together to develop new safety technologies such as better air bags and Automatic Crash Notification (ACN) to reduce the incidence, severity, consequences, and costs of crash injuries.

NHTSA's CIREN centers are now providing the nation with its most detailed medical and engineering analyses of serious injuries occurring in real world crashes. CIREN crash injury data and analyses are growing each year and are being organized by NHTSA into a powerful scientific knowledge base. The result is an increasingly useful research resource for discovering and defining opportunities to reduce the tragedies of deaths, injuries, disabilities and human suffering.

CIREN centers are educating and training graduate students in medicine and engineering. Many of these individuals will go on to make additional contributions to the practice of emergency care in hospitals and universities around the nation. In addition, a growing number of engineers are gaining medical knowledge and going back to jobs in the automotive industry. There they are able to apply their knowledge of injuries to design safer vehicles.

Thus, the work of CIREN researchers serves to improve the nation's safety infrastructure. CIREN researchers are sharing their safety findings at the federal, State and local level. This sharing of information conveys their life-protecting findings so that others may live, learn, and leave a legacy of a Safer America.

Jeffrey W. Runge, MD
Administrator,
NHTSA

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CIREN Program Report

National Highway Traffic Safety Administration (NHTSA)

Introduction

This is the NHTSA CIREN program's first Program Report. The report provides a description of the CIREN centers, the researchers, and their work. The individual centers have been operating for varying periods of time. While some centers have existed for nearly a decade others have been established more recently. This Overview chapter provides a brief description of the CIREN research process and presents a summary of research findings that have contributed to advancing the scientific understanding of serious crash injuries.

The CIREN Mission

The mission of NHTSA's Crash Injury Research and Engineering Network (CIREN) is to improve the prevention, treatment, and rehabilitation of motor vehicle crash injuries to reduce deaths, disabilities, and human and economic costs.

The CIREN Centers perform medical and engineering research on serious crash injuries that contributes to the efforts of NHTSA and the automotive industry to improve safety. CIREN research helps advance the development, testing, and evaluation of new technologies for the prevention of injuries and new techniques for more effective emergency medical transport and treatment of crash injured people.

The Goal

The goal of CIREN research is to identify opportunities for improvement in the prevention and treatment of crash injuries. This is accomplished through the coordinated efforts of medical researchers, working with engineers at NHTSA, the automobile industry, and academia to better understand the complex mechanisms of crash impact injuries.

This synergistic scientific approach enables engineers to learn how to improve vehicle designs, and medical practitioners to learn better means of treating crash victims. CIREN research provides the safety community with a "microscope" for the study of crash injuries in the real world. This is achieved by the collection and computerization of the extremely detailed crash and medical data contained in CIREN on serious injuries and their consequences.

The CIREN program strengthens America's highway safety infrastructure of people working at the national, State and local levels by providing a more realistic understanding of serious crash injuries. Valuable lessons are being learned from the study of real-world serious crash injuries in terms of both what is needed and what actually works.

CIREN research is also helping to advance the development of new technologies for improving crash safety, such as Automatic Crash Notification (ACN) systems. Research published in a series o papers co-authored by several CIREN investigators was influential in the enactment by Congress of the Wireless Communications and Public Safety Act of 1999, e.g., "*Automatic Crash Notification,*" "*URGENCY for a Safer America,*" and "*Reducing Highway Deaths and Disabilities with Automatic Wireless Transmission of Serious Injury Probability Ratings from Crash Recorders to Emergency Medical Services Providers*" (See citations in the Reference Section). The Wireless Communications and Public Safety Act's first finding states:

> "(1) the establishment and maintenance of an end-to-end communications infrastructure among members of the public, emergency safety, fire service and law enforcement officials, emergency dispatch providers, transportation officials, and hospital emergency and trauma care facilities will reduce response times for the delivery of emergency care, assist in delivering appropriate care, and thereby prevent fatalities, substantially reduce the severity and extent of injuries, reduce time lost from work, and save thousands of lives and billions of dollars"

A fundamental means of achieving CIREN goals is through research, education, and professional training. Numerous CIREN research findings have been published in scientific journals, and presented at international, national, state and local conferences. A unique feature of the CIREN program is its outreach efforts to educate and train a growing number of engineers and medical practitioners including physicians, nurses, paramedics, fire, rescue, and police (who often are the first emergency responders to crash victims). The result is a more informed and educated human infrastructure of safety and emergency medical care workers building a safer America.

The Safety Problem: Deaths, Disabilities, and Human & Economic Costs

The magnitude of the safety problem that the CIREN program is helping to addresses is enormous as is revealed in national crash statistics. Every year there are nearly 42,000 crash deaths (almost half of the victims die without transport to a medical treatment facility), 250,000 life threatening injuries, 500,000 hospitalizations, 2,000,000 disabled by injuries, and 4,000,000 emergency department visits. Annually in America, motorists are involved in nearly 17 million crashes involving nearly 27 million vehicles. Each year crash injuries result in approximately $100 billion in economic costs, or $350 billion in comprehensive costs that include value for pain and suffering.

Historically, more than 3 million people have been killed and 300 million injured in crashes in America – more than 3 times the number of Americans killed and 200 times the number wounded in all wars since 1776.

Many of the people killed in crashes are young. Half are under age 34, and the average is 40 years of age for all crash deaths. Crash fatalities and serious injuries have devastating impacts on families. Many children, uninjured physically in crashes, are hurt in other ways. No count of this tragic toll on children is kept, but serious crash injuries often result in long-term physiological, psychological, and sociological impairments. Such impairments often have devastating impacts on individuals, families, and society.

Motor vehicle crashes are responsible for large numbers of serious, life-threatening, injuries. National estimates of the number of serious crash injuries occurring each year in the US are:

- 70,000 Brain Injuries
- 4,400 Neck and Spinal Cord Injuries
- 80,000 Chest & Abdominal Injuries: Heart, Lungs, Spleen, Liver, & Kidneys
- 18,000 Hip and Pelvic Injuries
- 35,000 Leg, Ankle and Foot Injuries

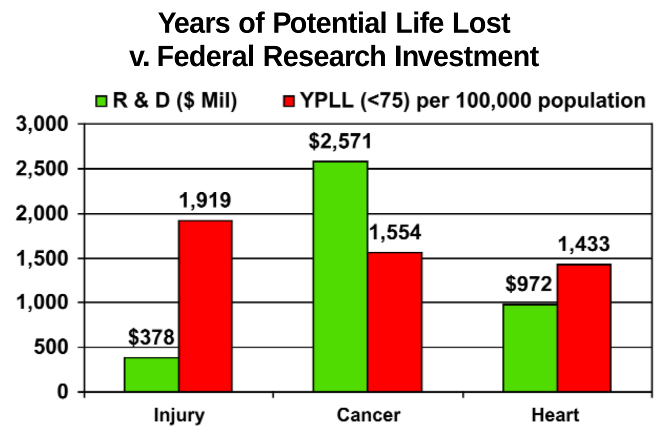
The above statistics do not include a much larger number of less serious injuries.

Nor do these statistics include injuries to pedestrians, motorcyclists, and heavy truck occupants, for which statistics on serious injuries are not available.

The need for greater scientific research on all injuries has been consistently recognized. In 1966, the National Academy of Sciences (NAS) published a landmark report *Accidental Death and Disability: The Neglected Disease of Modern Society*. In 1983 Congress, under the leadership of Representative William Lehman, enacted a law authorizing the Secretary of Transportation to request a second study on trauma by the National Academy of Sciences. In 1985 the NAS published *Injury in America – A Continuing Public Health Problem* that found "More than 2.5 million Americans have died from injuries since that report (the 1966 report) was issued." *Injury in America* recommended that a multidisciplinary approach be followed in research on the prevention and treatment of injury. The report recognized that research on crash injuries would not only improve motor vehicle safety, but also yield benefits in other fields of trauma prevention and treatment as well.

In 1999, the NAS published *Reducing the Burden of Injury*. This report once again highlighted the need for safety research to reduce all injuries and their tragic consequences. Figure 1 illustrates that the need is comparable to that of cancer and heart disease, but the resources allocated for crash injury research are much lower.

Figure 1.
The Injury Problem and Federal R&D Budgets for Leading Causes of Life Lost



Note: Figures show age-adjusted years of potential life lost (YPLL) before age 75 per 100,000 population vs. federal expenditures for R&D for three leading causes of death. Injury includes all unintentional injuries, homicide and suicide.

Reducing the Burden of Injury also specifically noted the value of CIREN as follows:

> "CIREN links trauma center clinicians and crash investigators in a nationwide computerized network. This enables engineers to better understand injury-producing mechanisms and to develop better criteria for vehicle safety design, while informing clinicians about emerging injury patterns, and thereby facilitating triage, diagnosis, and treatment of crash injuries."

The NHTSA and the international safety community have found that engaging multidisciplinary research teams in the study of trauma is fundamental to making progress in advancing automotive safety. In recent years, auto companies also have funded CIREN traumatology teams of physicians, engineers, crash analysts, and statisticians to find life-protecting solutions to injury.

The CIREN Program: Research to Reduce Fatal and Serious Injuries in Crashes

NHTSA and the Congress have long recognized the need for better scientific understanding of crash injuries, their causes, treatments, and consequences. Thus, with strong bipartisan support for many years, Congress has encouraged and provided for crash injury research at the front lines of serious injuries – trauma centers. The combination of engineering research to prevent injuries and medical research to preserve lives and livelihoods has been seen to advance safety – both at the local and national level.

The NAS report *Injury in America* recommended national coordination and management of injury research. In 1996, NHTSA Administrator Ricardo Martinez, MD initiated an effort to create the CIREN program to coordinate crash injury research then being performed at 4 trauma centers (New Jersey Medical School, University of Maryland, University of Miami, FL, and the Children's National Medical Center, DC). In 1997, with financial support from the General Motors Corporation, 3 additional trauma centers (at San Diego, California, University of Washington in Seattle, and the University of Michigan at Ann Arbor), as well as a computer network linking the 7 centers were created to form CIREN.

The wisdom of the nation's investment in such research is widely recognized in both the public and private sectors. In 1999, Mercedes-Benz funded an eighth CIREN Center at the University of Alabama (Birmingham). In 2000, Ford Motor Company funded a ninth CIREN Center at Inova Hospital in Fairfax, Virginia. In 2001, the Medical College of Wisconsin in Milwaukee became the tenth CIREN Center.

Learning Laboratory for Lifesaving: Serious Injuries Under the Microscope

The ten CIREN research teams are each affiliated with leading medical universities at major (Level 1) trauma centers. They are being linked by NHTSA into a computer network to create the nation's largest learning laboratory for lifesaving research. Together, the ten CIREN centers form a sophisticated system for the scientific study of serious crash injuries.

CIREN centers are a national, State, and local resource for the study of life threatening crash injuries. Examples of injury modes that are under investigation are devastating brain injuries, paralyzing spinal cord injuries, life-threatening internal organ injuries, crippling orthopedic injuries, and disfiguring burns.

The scope of CIREN covers the full range of injury research as pioneered by William Haddon, MD, the first Administrator of NHTSA. In accordance with Dr. Haddon's research matrix shown in Figure 2, CIREN researchers examine human, vehicle, and environmental factors operating in the pre-crash, crash, and post-crash phases of fatal and serious injury crashes.

Figure 2.
Haddon Matrix for Safety Research and Development

	Human	Vehicle	Environment
Pre-Event	Age, Experience Alcohol, Speed Distraction	Crash Avoidance Defects, Brakes Tires	Visibility Divided highways Signalization
Event	Belt use Human tolerance Helmet use	Crashworthiness Automatic restraints Airbags	Guardrails Median barriers Breakaway posts
Post-Event	Age Physical condition	Post-crash fires Fuel leakage ACN, URGENCY	Bystander care EMS system First responders

CIREN scientific research on crash injuries is performed in the real world, and in near-real time, as they occur and as they are treated. In addition, the researchers are in touch with the crash victims and their families for long-term follow-up so that the consequences and costs of injuries in both human and economic terms are more fully understood.

CIREN Progress: Medical & Engineering Research for a Safer America

CIREN centers have produced fundamental scientific research. Their "real world" findings have contributed to advancing NHTSA research programs in biomechanics, crashworthiness, and emergency medical services. Some of their research findings have been used by:

- **NHTSA** – in its research programs to improve crash biomechanics, emergency medical care, crashworthiness of vehicles, and public information & education;
- **National Transportation Safety Board (NTSB)** – in developing its recommendations on air bags and event data recorders (EDR);
- **Congress** – in its enactment of the Wireless Communications and Public Safety Act of 1999;
- **Federal Communications Commission (FCC)** – in setting national 9-1-1 policy;
- **The wireless and automobile industries** – in their development of Automatic Crash Notification (ACN) products and services;
- **The Federal Highway Administration** – in the development of its Intelligent Transportation Systems' Public Safety Initiatives;

- **The insurance industry** – in its efforts to reduce crash related losses;
- **The research community at large** – in its efforts to advance motor vehicle and highway safety

CIREN injury research teams are studying crash injuries of individuals at the local level, looking for patterns among their cases, and relating their local findings to national data on crash deaths and injuries. Through this scientific process they have been able to identify important problems worthy of more in-depth investigation by the broader safety research community.

CIREN Center Research Contributions:

Crash injury research contributions of the CIREN Centers over the years include many findings that currently are in various stages of use, development, testing, evaluation, deployment, and application. As these findings are applied over time, the safety benefits of the basic research will become a reality resulting in a Safer America.

Reducing Head and Neck Injuries:

- Documented the benefits of air bags in reducing the incidence and severity of brain injuries
- Increased knowledge of the need for improvements in air bag designs to reduce aggressive deployments
- Improved understanding of the need for safer child seats and their proper installation and use

Reducing Thoracic and Abdominal Injuries:

- Discovery of new injury patterns involving people in crashes protected by air bags and belts
- Improved understanding of injury mechanisms of 2-point seat belts
- Advanced understanding of the need for 3-point belts in rear seats to better protect children and adults from lethal abdominal injuries and crippling spinal cord injuries
- Increasing NHTSA knowledge of the nature of aortic injuries, often fatal, and the enormous potential for saving lives by early diagnosis of aortic injuries

Reducing Leg and Foot Injuries:

- Advanced the scientific understanding of lower extremity injuries, crash forces, occupant kinematics, and their significance in terms of long-term impairments and disability
- Explained injury mechanisms of acetabular (hip socket) fractures in angle offset frontal crashes
- Contributed to the development of safer vehicle structures to protect people from suffering leg injuries in frontal offset crashes as shown by improvements in vehicle crashworthiness found in crash tests by NHTSA and the Insurance Institute for Highway Safety

Improving Emergency Medical Care:

- Developing improved diagnostic tools to recognize occult, or hidden, internal injuries: This resulted in the NHTSA recommendation to "Lift the air bag & look for steering wheel deformation" and the "Look Beyond the Obvious" national poster campaign to improve triage and treatment of occult injuries
- Improving recognition of automatic seat belt-induced liver and spleen injuries for triage & treatment
- Designing, developing, and now validating URGENCY software for faster and smarter emergency medical care for crash victims
- Improving communications and organization of trauma systems for better care of crash victims
- Educating police, fire, and EMS care providers to recognize crash victims that require a higher index of suspicion of internal injuries and transport to a trauma center for treatment

Improving Automotive Safety Research:

- Provided medical guidance to the NHTSA on "Medical Indications for Air Bag Disconnection"
- Stimulated improvements in national data collection, crash intrusion measurements, statistical crash analysis files, and hospital studies
- Advanced the understanding of the need for restraint system improvements to protect older Americans with safer belt systems using load limiters, pre-tensioning retractors, and optimization for functioning in concert with air bags
- Supported improvements in crash test dummy design and instrumentation for lower extremity, pelvic, thoracic, and abdominal injuries
- Providing medical education on crash injuries to automotive industry safety engineers
- Educating engineers to the increased biomechanical safety needs of an aging population

CIREN studies are providing the safety community with a better understanding of the various factors that need to be addressed to improve the safety of American motorists. CIREN center teams are also advancing knowledge on a number of key issues concerning highway safety today:

- **Costs and Consequences of Crash Injuries:** By the year 2020, the U.S. Department of Transportation has projected that "fatalities and injuries could increase by 50 percent". CIREN Center researchers have advanced the understanding of the long-term consequences of serious crash injuries to individuals, families, and society. Leg and foot injuries were shown to be far more significant in terms of long-term impairment than previously understood. And CIREN researchers have shown that airbags that are currently in production vehicles are reducing serious brain injuries.

- **Aging & Injury Vulnerabilities:** The population of Americans age 65 or older is one of the fastest growing demographic groups. By the year 2020, that age group will have grown to 53 million from today's population of 35 million. Currently about 7,000 older Americans are killed in crashes each year. CIREN researchers have highlighted the increasing vulnerability to crash forces as people age. In crashes of a given severity, the probability of suffering a serious injury increases as the age of the occupant increases. For example, in a 30 mph frontal impact crash, a 25 year-old male has a 15% probability of suffering a serious injury. In a crash of the same severity, a male of age 75 faces four times the risk: a 60% probability of being seriously injured.
- **Gender & Size Crash Protection Needs:** CIREN researchers have been advancing the scientific understanding of gender and occupant size differences in crash injury prevention and treatment. The effects of gender can be appreciated by examining the effect of gender on injury risk. If the occupant in a 30 mph frontal impact crash is a female (instead of a male as in the above crash), at age 25, her risk of suffering serious injury is 22%, and at age 75, her risk is 70%. CIREN research has shown that occupant size also is important to reducing crash injury consequences. Occupants of short stature, often females, are at greater risk of internal injuries. CIREN center studies have shown that if occupants of short stature or large girth are in frontal crashes, emergency medical care providers should apply an increased index of suspicion for the possibility of occult, or hidden, internal injuries that could be fatal if not properly diagnosed and treated.
- **Advanced Dummies for Improved Occupant Restraint Systems for Protection from Thoracic, Abdominal, Pelvic and Leg injuries:** CIREN research has supported the need to develop advanced crash test dummies to better represent human injuries found in serious injury crashes. This research also points to the need for improved injury criteria for complex Knee-Thigh-Hip injuries. Specifically, advanced dummies now measure crash forces for loads on the chest and abdomen so that better belts and air bags can be designed. Advanced dummies now measure forces to the pelvis at varying angles to better protect against injuries in a wider variety of crash conditions. And advanced dummies now have the capability to measure crash forces to the foot, ankle, and upper and lower leg so that greater protection of these parts of the body can be designed into new vehicles.
- **Automatic Crash Notification (ACN):** CIREN research has identified the need for ACN systems. Moreover, CIREN researchers have developed Urgency computer software for ACN systems that measure crash severity and automatically estimate the probability of a serious injury being present in that crash. This software will improve the triage, transport, and treatment of crash victims to save lives and reduce disabilities. Ford Motor Company is currently demonstrating an ACN system, with URGENCY software, in its safety concept Rescue Car.

For the motoring public, CIREN center researchers, the NHTSA, the automotive industry, and emergency medical care providers are working together to create a Safer America.

NHTSA CIREN Network: Researchers, Facilities, Data, Analyses, and Insights

CIREN is the nation's network of medical and engineering researchers working on safety at leading trauma centers. The NHTSA has established 10 CIREN Centers, 7 federally funded (3 of which were originally funded by GM), 2 privately funded, and one, at the Medical College of Wisconsin, that is self-funded. NHTSA has organized the ten CIREN Centers into a Network for the collection, analysis, and sharing of crash injury data. The Centers communicate electronically over a secure Wide Area Network established by NHTSA.

Detailed data from serious injury crashes are incorporated into a national knowledge base for safety analyses. The CIREN database contains the most detailed information on crashes and injuries available for safety research. Currently CIREN centers use this database in collaborative research. In the near future, the wider safety community also will be using it to advance the scientific understanding of opportunities to improve motor vehicle injury prevention and treatment.

Key data including X-ray, MRI, and CAT-Scan images are organized in a core repository so that all centers can review the status of cases across the network. Cases, in whole or in part, may be reviewed electronically so that individual center expertise may be shared in evaluating a case. Videoconferences are periodically conducted wherein cases are reviewed simultaneously across multiple centers.

The NHTSA National Automotive Sampling System - Crashworthiness Data System (NASS CDS) and CIREN operate on the same network and use the same basic crash data elements. CIREN expands upon these basic elements to include a detailed medical dataset. Both systems code all injuries using the NASS adaptation of the AIS codes. In addition, CIREN assigns appropriate ICDM-9 codes to injuries for more specificity.

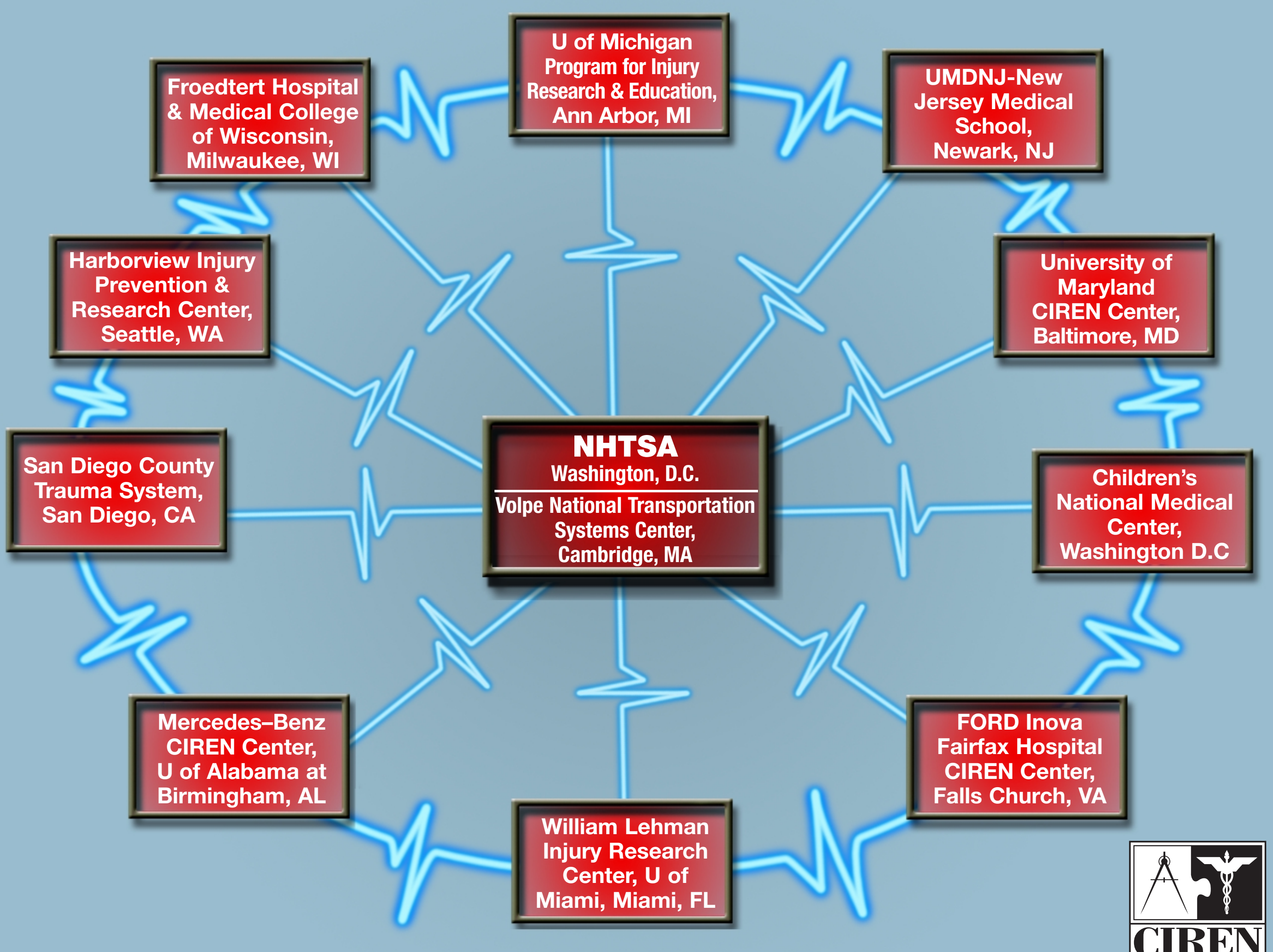
NASS CDS provides national estimates of the incidence of injuries to occupants in light vehicles in tow-away crashes. CIREN data enable the detailed study of more severe injuries occurring in crashes. An example of how CIREN researchers use both CIREN and NASS data illustrates the scientific process that can lead to discoveries of safety problems and solutions. First, CIREN researchers observe injury patterns in their trauma centers such as hidden, and potentially fatal, liver injuries in vehicles with 2 - point belts. Second, they check the CIREN database to see if the observed injury pattern is present beyond their local center. Third, the NASS database is examined for indications that the problem may be of national scope. If a safety problem of national dimensions is confirmed, then solutions are developed such as education of paramedics to better recognize hidden liver injuries and education of motorists to the importance of buckling up the lap belt as well as the shoulder belt.

CIREN cases involve people who are injured in motor vehicle crashes and transported to a participating Level 1 trauma center. Other criteria for being selected as a CIREN case include a focus on frontal impacts involving late model year cars (less than 8 years old), any impact where a child is injured and transported to the trauma center, all fire related cases, and rollover with fewer than two quarter turns. The cases researched by these centers have helped in providing an understanding of injury profiles such as injuries associated with and without air bags and "hidden" injuries such as bowel perforations in children or liver lacerations in adults.

CIREN crash investigators depend on the participation and cooperation of Police Departments, Fire Departments, Emergency Medical Services professionals, Social Workers, Crash Investigators, Nurses, Physicians, Medical Examiners, Coroners, hospitals, tow yard operators, garages, city vehicle pounds, and the individuals involved in the crashes. Cooperation from law enforcement agencies enables CIREN researchers to obtain police crash reports that provide key information on the location of the crash and vehicles involved in crashes.

CIREN crash investigators inspect and photograph vehicles, interview vehicle occupants, and photograph crash scenes in order to reconstruct the crash. CIREN medical research teams collect extensive medical data on the

Figure 3.
CIREN Computer Communications Network and Database



injured occupant as it is obtained during and after his/her hospitalization. The medical data includes descriptive text, drawings, x-rays and other pertinent medical images and photographs.

CIREN research teams, crash investigators and, as required, additional experts meet periodically to review their cases and analyze the injury mechanisms. These review conferences associate injuries with vehicle intrusions, occupant contacts, and biomechanical mechanisms.

The CIREN database consists of the NASS CDS data set plus additional medical and injury variables. The NASS CDS data set contains variables that describe an automotive crash including but not limited to:

– Crash Type
– Vehicle Make, Models, and Body Types
– Crash deformation classification (CDC)
– Crush Profiles
– Delta Vs
– Intrusions
– Occupant Contacts

The CIREN medical and injury data elements include tables for:

– Co-morbidity
– Diagnostic Procedures
– Complications
– Operative Procedures
– Medical Images
– Disability Measurements
– Emergency Medical Response
– Emergency Medical Treatment
– Vital Signs
– Physiologic Measurements
– Injury Location
– Ventilation Periods
– Intensive Care Unit Stays

Each CIREN case concerns one injured occupant in a motor vehicle crash. The medical data listed above is linked to the crash data. Due to the sensitivity of some of the medical information collected, special steps are taken to protect the privacy of individuals. Personal and location identifiers (e.g., name, address, telephone number, precise accident location), as well as detailed medical information (e.g., patient photographs, X-rays, medical histories) are not publicly released.

NASS CDS provides national estimates of the incidence of injuries, however, detail is limited for the more severe injuries. Often detailed injury data is needed for research on improvements in medical response, therapy, and/or vehicle design so as to decrease morbidity and mortality. On the other hand, CIREN data does not provide the total national picture of crash injuries. NASS collects data on 10 times as many crashes each year as does CIREN. CIREN analyzes many fewer crashes, about 400 each year, than NASS. But, the more detailed examination of serious crash injuries, their treatments, and patient outcomes in CIREN helps engineers and physicians to look for opportunities to make advances in injury prevention and treatment.

In Figures 4a, 4b & 5, injury severity levels are used as measured by the Abbreviated Injury Scale (AIS). Injury severity as measured in the AIS system means a greater threat to life as the AIS number increases, but it is not a measure of long-term morbidity. MAIS is a measure of the maximum injury recorded for the injured occupant.

Figure 4a compares the national distribution of occupant injuries by level of severity, as measured in NASS CDS 1997-2000 cases, against all cases in the CIREN system, currently about 1,250 cases. The NASS CDS data shown is weighted to represent the national crash injury experience. As can be seen in Figure 4a, the distribution of

Figure 4a.
CIREN & NASS Weighted Data Comparison by Maximum Injury Severity Level

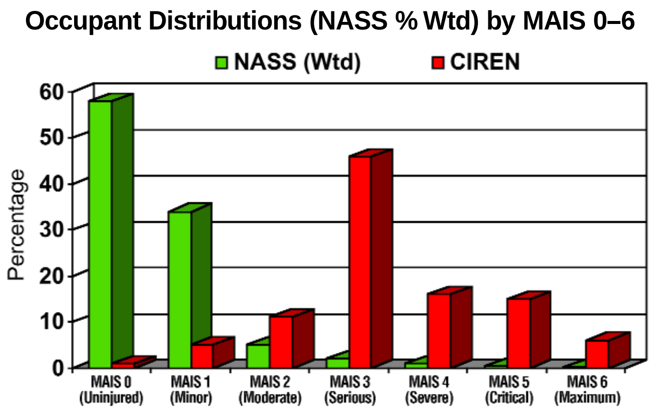
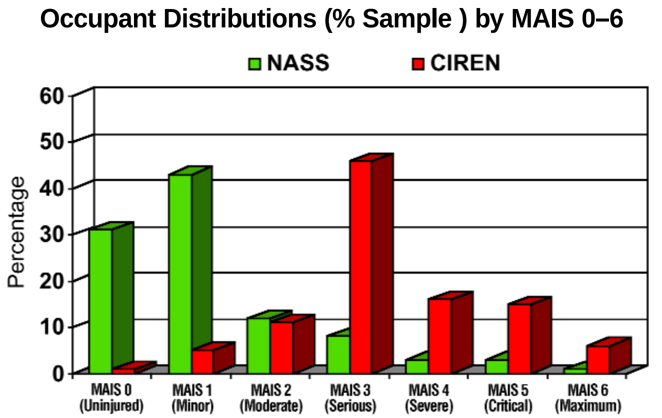


Figure 4b.
CIREN & NASS Unweighted Data Comparison by Maximum Injury Severity Level



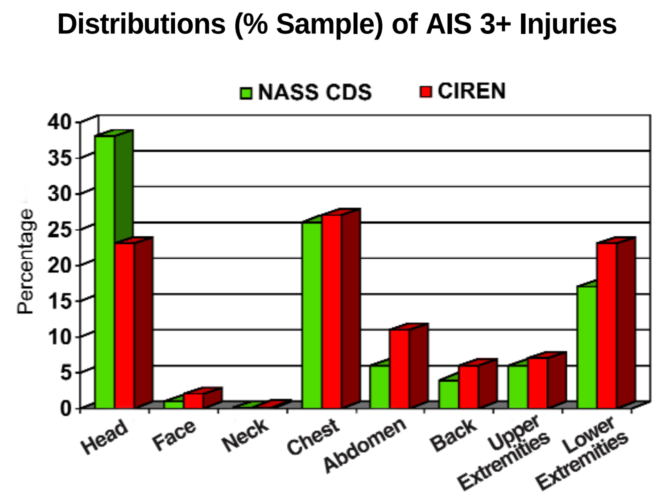
CIREN injuries tends to be more severe than those found in the nationally representative NASS CDS system. This is as it should be since CIREN is designed to better understand serious injuries, while NASS CDS is designed to provide a statistical picture of the full spectrum of crash injuries.

Figure 4b compares sample distributions showing the percent of samples in both NASS and CIREN by MAIS level. In this figure, NASS data are unweighted. Figure 4b shows that the CIREN sample focuses more heavily on the serious injuries as it is designed to do. Together, figures 4a and 4b show how CIREN complements, but does not substitute for NASS.

Below, Figure 5 compares the sample distribution of serious injuries (AIS 3+) in NASS CDS 1997-2000 cases with the sample distribution of CIREN cases by body region.

Note that CIREN has a similar distribution of serious injuries in the various body regions as is being collected in NASS. This indicates that CIREN is faithfully reflecting the distributions of serious injuries by body regions found in NASS.

Figure 5.
CIREN and NASS Serious Injury Data Comparison by Body Regions



The CIREN database with about 1,250 cases is now at the phase of becoming a new and useful tool for the study of serious crash injuries. The CIREN database complements and supplements NASS. The CIREN database is analogous to a new "microscope lens" for the more detailed study of serious crash injuries, and is now being used in conjunction with NASS. The CIREN database provides valuable medical and engineering biomechanics data whereas the NASS provides the nationally representative picture of crashes and injuries. Together, these two "lenses" create a valuable new tool for the advancement of automotive safety.

Thus, CIREN researchers and, increasingly, safety researchers nationwide are now using and applying CIREN data and its research findings to improve safety. CIREN is advancing safety in both the prevention and treatment of injuries that seriously threaten lives and livelihoods.

CIREN Public Information Dissemination:

NHTSA has provided for public information and participation through the following:

- CIREN Conferences:

  University of Michigan, Medical Center, Ann Arbor, October 20, 1997

  University of Michigan, Medical Center, Ann Arbor, September 15, 1998

  San Diego County Trauma System, San Diego, CA, October 28,1999

- In lieu of annual meetings, in an effort to disseminate CIREN information more quickly, NHTSA began holding CIREN quarterly public meetings:

  Lower Extremity Injuries (May 5, 2000)

  Side Impact Crashes (July 21, 2000)

  Thoracic Injuries (Nov. 30, 2000)

  Offset Frontal Crashes (March 16, 2001)

  CIREN Outreach Efforts (June 21, 2001)

  Injuries Involving Sport Utility Vehicles (Sept. 6, 2001)

  Age Related Injuries [Elderly and Children] (Dec. 6, 2001)

- CIREN public presentations are made available on the NHTSA web site at http://www-nrd.nhtsa.dot.gov/departments/nrd-50/ciren/CIREN.html

- CIREN cases are publicly available in sanitized form for privacy protection as follows:

  Internet access to completed cases at http://www-nrd.nhtsa.dot.gov/bin/cirenfilter.dll

  Public Workstation at DOT Headquarters, 400 7th St. S.W., Washington, DC, 20590, in Room 6220.

Children's National Medical Center

A Pediatric CIREN Center

CIREN Program Report

I. Children's National Medical Center CIREN - Overview:

A. History

In 1870, Children's Hospital opened its doors to provide health care for the large number of children orphaned by the Civil War. One-hundred-and-thirty years later, it remains the only health system in the region dedicated exclusively to the care of children.

Children's National Medical Center (CNMC) is the designated Level I Pediatric Trauma Center for the District of Columbia and five Maryland counties. It also provides care to children from adjoining counties in Virginia. There are an estimated 365,000 children, under 15 years of age, in the Washington metropolitan area, served by CNMC.

B. Research Capabilities

CNMC does more than treat childhood illness; it develops treatments as well. Through the Children's Research Institute (CRI), basic and clinical investigators utilize cutting-edge technologies to fight childhood disease nationally and internationally. CRI is a free-standing research institute in Children's National Medical Center, a major academic pediatric medical center affiliated with The George Washington University in Washington, DC. Research at CRI aims to better understand the prevention, management, and treatment of the diseases of infancy, childhood, and adolescence.

CRI consists of six research centers; the CNMC CIREN team is housed in CRI Center VI. The overall goal of Center VI is to facilitate health services and clinical research throughout CNMC. Center VI is home to 47 funded projects and many of its awards, like the CIREN project, are for research in the area of injury prevention and control.

C. Crash Research at CNMC

Despite numerous prevention efforts, motor vehicle crashes remain a leading cause of death among children. Traditionally, biomechanical data based on cadaver or anthropomorphic test devices has been used by researchers to improve safety. Although the use of these surrogate data sources provides directional guidance, neither cadavers nor dummies react in the same way as humans. However, there is a way to obtain valuable human biomechanical data, and that is to have personnel at Level I trauma centers collect it as injured motor vehicle crash occupants seek treatment. When this information is supported with crash investigations and biomechanical analysis, a more complete picture can be obtained on what actually happens to the human body during a crash.

With this idea in mind, NHTSA has been funding hospital-related studies since the 1980's. In 1991, the Office of Crashworthiness Research initiated the Highway Traffic Injuries Studies and CNMC was one of four level I trauma centers to receive funding to collect detailed injury information on restrained motor vehicle occupants. In 1996, the motor vehicle crash research being conducted at the four trauma centers evolved into CIREN, and additional centers were added to the network. CIREN is able to provide the detailed level of real-world biomechanical crash data and accurate prospective injury information needed for crash injury prevention. CIREN is different from the typical multi-center research group convened to investigate a single phenomenon. In essence, it is a standing multi-center research organization with the capability to investigate changing research priorities.

CNMC is the only site in the CIREN network dedicated solely to the study of pediatric crash injuries. Our data is used by organizations such as the American Academy of

Pediatrics, the National SAFE KIDS Campaign, child restraint manufacturers, and other child passenger safety groups to design prevention programs, make technological improvements to restraints and vehicles, and to develop advocacy and policy recommendations.

D. CNMC CIREN Team

Martin R. Eichelberger, MD, Professor of Surgery and of Pediatrics, George Washington University, Washington, D.C. and Director of Emergency Trauma and Burn Service, Children's National Medical Center, Washington, D.C. is the CNMC CIREN Principal Investigator. Dr. Eichelberger is also President and Co-Founder of the National SAFE KIDS Campaign in Washington, DC as well as the Medical Director of Emergency Medical Services for Children (EMSC). He is a nationally recognized pediatric trauma surgeon and injury prevention advocate.

Elizabeth A. Edgerton, MD, MPH, is a member of the Division of Emergency Medicine at Children's National Medical Center where she is also a co-investigator on the CNMC CIREN project. Dr. Edgerton has been involved in injury prevention for the last 8 years, primarily focusing on community-based interventions and injury surveillance. Projects include developing and evaluating a child passenger safety program for elementary school children in a predominately Latino community. She holds an academic appointment as an Assistant Professor of Pediatrics at the George Washington School of Medicine and Health Sciences.

Dorothy Bulas, MD, is a radiologist at Children's National Medical Center. She works with the CNMC CIREN team to document injuries in the form of X-rays, MRI, CAT scans, and other radiological imaging. These images all become a vital component of the CIREN database.

Kelly Orzechowski, MPH recently received her Master of Public Health degree from the George Washington University with a concentration in Maternal & Child Health. She is currently the Project Coordinator for the CNMC CIREN site and has been with the project since August 2000.

Helma Parikh, BS, EMT-B received her Bachelor of Science degree in Health Education. She joined the CNMC CIREN team as our Outreach Coordinator in August 2001. Her primarily responsibilities include developing relationships with fire & rescue, police and allied health professionals to better promote and incorporate CIREN within the community.

Patrick McLaughlin, BS joined the CIREN team as a research assistant in June 2001. His many responsibilities include interviewing potential study subjects to determine their suitability for the enrollment, documenting medical information for each case, and entering data in CIREN.

Crash reconstructions are performed by *Accident Cause & Analysis*.

II. Background & Significance

Motor vehicle crashes are a most significant cause of childhood injury, death, and disability in the United States. According to 1998 statistics from the Centers for Disease Control, motor vehicle crashes accounted for approximately 50% of deaths from unintentional injury (2,856 deaths) to children less than 15 years of age.[1]

While child safety seats can be up to 71% effective in saving lives when used properly,[3] they are used with just 85% of infants and 60% of toddlers.[2] Among children 4-8 years of age, only 5% currently ride in a booster.[6] Of those who do use child safety seats, approximately 85% are used incorrectly, and we know little about misuse patterns, their role in injuries, or how to correct misuse.[3] Although effective child restraint usage has come a long way, it is imperative that we further study crashes to determine whether improvements in equipment and design and other preventive measures can be identified to reduce injury.

A. Child Restraint Systems

The purposes of adult and child motor vehicle restraint systems are to prevent ejection from the vehicle and to minimize contact with the vehicle's occupant compartment. They work by distributing crash forces widely over the body's anatomically strongest components and by reducing the rate of deceleration. However, the similarity of purpose is contrasted by wide varieties in design, availability as part of standard or optional automotive safety features, degree of consumer choice, and availability of passive restraint measures. Restraint systems used by adults are nearly always standard or optional safety features installed by the vehicle's maker at the point of manufacture, whereas those used by children are usually purchased separately from the vehicle and must be installed by the owner. Further, unlike adult restraints, where "one size fits all," different restraint devices are required for children of different ages and sizes. Broadly speaking, there are three types of active restraint systems in common use among children in the United States: safety seats, booster seats, and safety belts. The design, use, and effectiveness of each type of restraint are discussed below.

B. Infant and Child Safety Seats

The rear-facing infant safety seat is designed for children under 20 pounds and under 1 year of age (Figure 1). Most infant seats allow the baby to sit in a semi-upright position

Figure 1
Infant Seat
Rear-Facing Only

Figure 2
Convertible Seat
Rear-Facing

Figure 3
Convertible Seat
Forward-Facing

with the back of the seat reclined at a 45° angle. The seats are designed to broadly transfer frontal crash forces over the infant's back while providing support for the head. The safety harness provides containment within the seat.

If a child weighs more than 20 pounds prior to one year of age or if his or her head extends beyond the top of the infant seat cushion, the child can "move up or graduate" to a convertible safety seat that is installed rear-facing in the vehicle (Figure 2). Once the child has reached both 20 pounds and one year of age, the convertible safety seat may be installed forward-facing in the vehicle (Figure 3). However, most convertible safety seats can accommodate children rear-facing until they are 30-35 pounds. Child passenger safety advocates recommend keeping children rear-facing as long as possible until they reach the manufacturer weight limit for the seat (30-35 pounds). Once a child exceeds the rear facing weight limit for a convertible seat, the seat must be installed forward facing. Forward-facing seats are the preferred method of child restraint until the child's weight exceeds 40 to 45 pounds.

C. Booster Seats

Children between the ages of 4 and 8 years old represent an important at-risk population for motor-vehicle occupant protection. Having outgrown child safety seats designed for younger passengers, children in this age group frequently sit unrestrained or are placed prematurely in adult seatbelt systems. In fact, children between the ages of 5 and 9 years represented one of only three age groups that did not demonstrate a significant decline in motor vehicle crash morbidity and mortality over the 20-year period of 1978-1998 (65-74 years and 75+ years being the other two groups).[2] Yet we have an effective intervention for these injuries—booster seats.

The two types of booster seats commonly available to US consumers are "belt-positioning boosters" which elevate the child to provide a better safety belt fit for small children and a "shield booster" in which a hinged, padded bar (or shield) locks across the front of the device to secure the child in the seat; the padded shield is designed to decelerate the child in the event of a crash, while preventing contact with the occupant compartment (Figure 4).

Figure 4
Shield Booster

The shield booster and the "belt-positioning booster" are the two types of booster seats available to US consumers. Shield booster seats were designed many years ago for use with vehicle lap belts because prior to 1989, those were the only restraint systems available in rear seating positions. There is only one model on the market today. It is designed so that the vehicle lap belt routes across the front of a hinged, padded bar (or shield); the padded shield is designed to decelerate the child in the event of a crash, while preventing contact with the occupant compartment (Figure 4). A shield booster is recommended for use with children between 30 and 40 pounds.

Figure 5
High-Back Booster

Belt-positioning boosters are typically designed for use with lap/shoulder belts, repositioning the on-board safety belts to better fit small children (Figure 5). Automobiles sold in the United States were not required to provide three-point restraints for the outboard rear seats until model year 1990, this type of booster seat, which many consider superior to the more common low shield booster, currently is not widely used in the United States.

Because booster seats are not required by law in most states, they have not come into sufficiently widespread use for their efficacy to be measured in population-based crash studies. Their potential efficacy has been demonstrated, however, with test dummies in crash simulations.

D. Safety Belts

Safety belts designed for adults do not protect children as well as safety seats designed with pediatric proportions in mind. Lap/shoulder belts result in hyperflexion-related injury to the abdominal viscera and lumbar spine of children. Adult three-point restraint systems are not adequate for children who have not attained most of their adult stature. Several unique anatomic features of infants and children are believed to contribute to the nature and severity of the injuries they sustain as motor vehicle occupants. These important features include different anatomic proportions of body mass from adults, and the immaturity of skeletal tissues. For example: the small anterior-posterior diameter of children, their poorly developed anterior iliac crests, and their more pliant skeletal systems suggest that safety belts cannot protect children as well as they protect adults. Seatbelt misuse puts children at additional risk for injury. The types of safety belt misuse (excluding non-use) commonly seen include restraining two occupants with a single belt, allowing a loose fit for the shoulder belt, re-routing the shoulder belt under the child's outboard arm, and routing the shoulder belt behind the child's back.

Figure 6
Proper Belt Fit

III. Research Aims

By providing information that will link disabling injuries to features of automobile interiors and restraint systems resulting in these injuries, the ultimate goal of CIREN is to provide specific information needed for modifying existing designs of automobile interiors and restraint systems to reduce mortality and morbidity associated with motor vehicle crashes. More specific aims are as follows:

- To document injury patterns associated with different restraint systems and specific types of crashes.
- To identify opportunities to improve motor vehicle or restraint system designs to prevent child injuries.
- To estimate, by comparison, the relative effectiveness of different kinds of restraints used by children.
- To educate and train professionals to improve treatments and outcomes.

IV. Research Findings

Dissemination of our research findings is conducted through several avenues. Findings are submitted for publication in peer-reviewed, scientific journals and for presentation at national meetings and conferences. A complete listing of CIREN-related publications and presentations can be found in Appendix A. Summaries of our research findings are listed below.

A. Seatbelt Injuries

Martin Eichelberger, MD became interested in further study of pediatric injuries associated with motor vehicle crashes after reviewing cases of injuries associated with lap belt use. All trauma admissions to CNMC during a three-year period (n=395) were reviewed to determine the frequency of abdominal and spinal injury in children wearing safety belts. Ten of the 95 children (10.5%) wearing safety belts sustained a significant "seatbelt syndrome" or "lapbelt complex" injury to the lumbar spine or intestines; seven of these children also experienced head injuries.

The "lap belt syndrome" is caused by the transfer of deceleration forces to the spine. The typical complex of belt-related injuries includes a hallmark lap belt ecchymosis (Figure 7), and lumbar fracture or distraction (Figure 8), with or without spinal cord involvement. Damage to the spinal cord is most often is caused by blunt, non-penetrating trauma rather than by laceration or transection. These mid-lumbar spinal injuries may be associated with paraplegia and life-threatening visceral injury. Additionally, abdominal organs may be compressed between the belt and the spine resulting in perforations of the hollow viscera (Figure 9), and contusions or lacerations of the solid organs. These injuries result in considerable physical disability, emotional distress for the child and family, lost future productivity, and astronomical national health care expenditures.

Figure 7
Lap Belt Ecchymosis

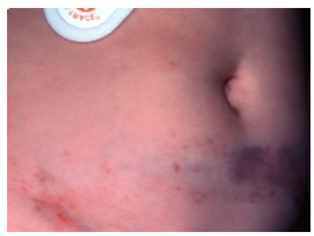


Figure 8
Spinal Fracture

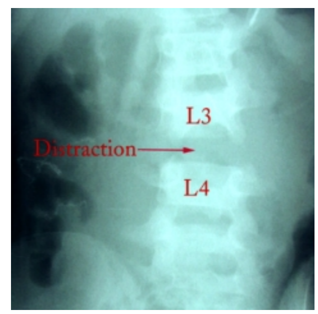
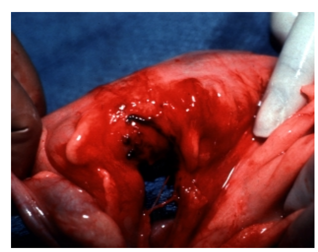


Figure 9
Intestinal Rupture



Several factors place children at special risk of seat belt syndrome. Due to a child's shorter torso length, shoulder straps frequently ride across the neck and face (Figure 10) increasing the likelihood that the child will place the strap behind his or her back. Three-point belts have been installed in cars produced since 1990, but there are still millions of cars on the road with only two-point restraints in the rear seats. Behavioral characteristics of children put them at further risk of lap belt syndrome. Restrained children usually sit in a more slouched posture than adults, increasing the likelihood that the lap belt will ride up across the abdomen. Even when the lap belt is properly placed across the iliac crests of the pelvis, children often move around altering the proper fit of the belt or they loosen the belts to allow greater freedom of movement.

Figure 10
Incorrect Belt Fit

B. Airbag Injuries

Air bags can save lives, but they also can cause serious injury or death, especially to children. Since 1993, more than 20 infants and 99 children have been killed in low- or moderate-speed crashes by deploying air bags.[7] Infants in rearward-facing safety seats in front seats are particularly at risk of death if the airbag deploys. This is largely because the infant's head is close to air bag cover. In a crash, the airbag deploys out of its housing in the dashboard at tremendous speed causing the safety seat back to crack. This results in severe head trauma. Children in forward-facing safety seats in the front seat also have a high risk of traumatic brain injury if the air bag deploys. In addition, they are at increased risk for cervical spine injury resulting from hyperextension. Thus, NHTSA child passenger safety guidelines require children less than 12 years of age to be seated in the back of a vehicle.

Figure 11
Airbag Deaths to Children by Year

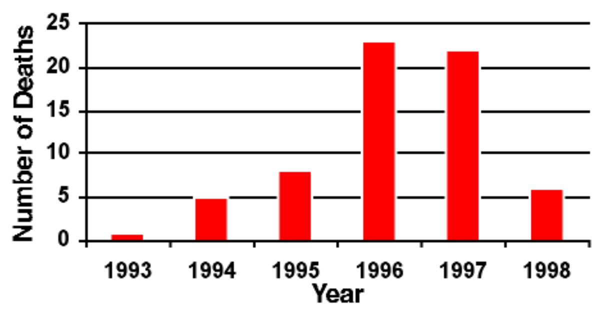
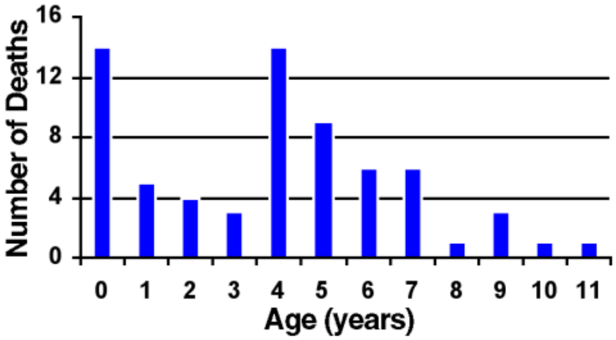


Figure 12
Airbag Deaths to Children by Age



C. Restraint Misuse Research

It is estimated that safety seats are 70% effective in reducing the risk of death or serious injury when used correctly.[3] However, safety seat misuse can greatly diminish the effectiveness of the devices, and there are numerous opportunities for misuse due to the complexity and variability of seat designs. Misuse rates continue to be unacceptably high in the United States.

For optimum protection, seats must be securely anchored and correctly located within the vehicle, facing the correct direction depending on child age, must have the shoulder straps adjusted properly, and the child must be correctly harnessed within the seat.

One of the most recent and ambitious efforts to assess child restraint misuse was undertaken by The National SAFE KIDS Campaign. A study of more than 17,000 safety seats showed that approximately 85% of children were restrained improperly (Figures 13-14). 3 Since NSKC does not collect injury data on children in crashes, they partnered with CIREN to demonstrate the consequences of such misuse. In fact, three CIREN cases were included in their national report on safety seat misuse.

Figure 13
Common Misuses for Rear-facing Seats

- Seat Belt Not Tight (61%)
- Not at a 45° Angle (35%)
- Harness Straps Not Snug (35%)
- Harness Straps Not At or Below Shoulders (16%)
- Seat Belt Not in Locked Mode (12%)
- Not Rear-Facing Until 1-year & 20 lbs. (11%)

Figure 14
Common Misuses for Forward-facing Seats

- **Seat Belt Not Tight (65%)**
- **Harness Straps Not Snug (35%)**
- **Harness Straps Not At or Above Shoulders (23%)**
- **Retainer Clip Not at Armpit Level (19%)**
- **Seat Belt Not Locked (14%)**

Studies have shown that safety seat misuse is associated with greater risk of severe injury. Research by our team advances those findings by looking at injury risk by categories of misuse. The term "misuse" is used more generically to include incorrect and/or inappropriate restraint use. Appropriateness refers to whether the restraint used was the safest available for the age/size of the child. Correctness refers to technical aspects of safety seat use. (Table 1).

In an analysis of CIREN data, misuse was found for 84% of restrained children (n=121). Improperly restrained children experienced a higher mean Injury Severity Score (ISS) than properly restrained children ($p < .05$) and incurred medical charges more than 2 times higher ($p<.05$). The most common type of misuse was failure to use a restraint that was appropriate for the child's size and age. More than 76% of children were restrained inappropriately. Children between 40-80 pounds were at greatest risk since they should have been restrained in a booster seat but were most commonly restrained by the vehicle's safety belt. Infants were also at considerable risk of being incorrectly restrained in forward facing safety seats before reaching 20 pounds and one year of age.

Many reports exist of severe injury to the cervical spine to infants and very young children inappropriately restrained in forward-facing safety seats. The large size of an infant's head, relative to the size of its body, the laxity of the cervical ligaments, a higher center of gravity, and the underdevelopment of the cervical musculature all contribute to this phenomenon. Typically injuries involve distraction or dislocation of the vertebral column at or near its attachment to the skull, resulting in transection of the spinal column and, if the child survives, quadriplegia. Even if a child does live, he/she remains at high risk of fatal respiratory disease and rarely survives more than a few years.

Incorrect use of restraint systems was also common (36% of cases). Placement of the shoulder belt behind the back and failure to anchor a safety seat to the vehicle were the most frequent errors.

Our data indicates that except in cases of blatantly incorrect restraint use (failure to buckle safety straps), it is generally more dangerous to use inappropriate restraints than it is to use restraints somewhat incorrectly. The high injury rate among children who were correctly but inappropriately restrained suggests that we need to change our message to parents. It is not enough to emphasize using a restraint correctly; it is equally, if not more important, to enable parents to choose the correct restraint for their children based on the child's size and weight. NHTSA's current child safety guidelines are shown in Table 2.

Table 1.
Correctness versus Appropriateness of Child Restraints

	Correct (how the CRS was used)	**Incorrect**
Appropriate (who was in the CRS)	Child is proper weight & height for CSS. Child is facing proper direction. CRS is best choice f/ weight, height, age. CRS is installed and adjusted correctly.	Child is proper weight & height for CSS Child is facing proper direction. CRS is best choice f/ weight, height, age. CRS is incorrectly installed or adjusted
Inappropriate	Child is not proper weight and height for CRS used; there is a better option CRS is installed and adjusted correctly (seat at proper angle, harness straps at proper level, threaded correctly, etc).	Child is not proper weight and height for CRS used; there is a better option CRS is incorrectly installed or adjusted (not tightly secured to vehicle, harness straps not routed properly or too loose…)

Table 2. Child Passenger Safety Guidelines Buckle Everyone. Children Age 12 and Under in Back!			
	Infants	**Toddlers**	**Young Children**
Weight	Birth to 1 year up to 20–22 lbs.	Over 1 year and over 20 up to 40 lbs.	Over 40 pounds up to 80 lbs.
Type of Seat	Infant only or rear-facing convertible	Convertible / Forward-facing	Belt-positioning booster seat
Seat Position	Rear-facing only	Forward-facing	Forward-facing
Always Make Sure:	Infants up to one year and at least 20 lbs. must ride in rear-facing seats. Harness straps at or below shoulder lever	Harness straps should be at or above shoulders Most seats require top slot for forward facing	Belt positioning booster seat must be used with both lap and shoulder belt. Make sure the lap belt fits low and tight across the lap/upper thigh area and the shoulder belt fits snug crossing the chest and shoulder to avoid abdominal injuries.
Warning!	All children age 12 and under should ride in the back seat.	All children age 12 and under should ride in the back seat.	All children age 12 and under should ride in the back seat.
[For more information on child passenger safety please visit www.nhsta.dot.gov]			

D. Predictors of Injury Severity

In an analysis of CIREN data, we identified certain predictors of injury severity. Crash type played a significant role in the severity of the injuries experienced by the children. Children in non-frontal (mostly lateral) crashes had significantly lower Glascow Coma Score (GCS) on admission ($p < .05$) and higher mean Injury Severity Score (ISS) ($p < .05$) than children in frontal crashes. Forty five percent of side impact versus 26% of frontal impact crashes resulted in injuries with an Abbreviated Injury Score (AIS) of 3 or greater. Children in non-frontal crashes were at increased risk for head, C-spine, thoracic, and extremity injuries, but sustained significantly fewer abdominal and lumbar spine injuries than children involved in frontal crashes.

There were no differences in injury severity between children in front and rear seating positions, however, differences in the likelihood of injury to different body regions by front versus rear seating position were observed. Children in the front seat were more likely to sustain injury to the face ($p<.05$) and upper extremities ($p<.05$) than children sitting in the rear.

Two additional aspects of restraint use, appropriateness and correctness of use, were used to assess child passenger safety in a crash. The children were divided into 4 weight classifications (0-20 pounds, 21-40 pounds, 41-60 pounds, and greater than 60 pounds) based on the weights recommended by safety experts and seat manufacturers for rearward-facing infant safety seats, forward-facing child safety seats, booster seats, and lap/shoulder belts.

Incorrect restraint use occurred in approximately one-third of the cases (34.4%). While most of the misuse involved safety seats, belts were also incorrectly used. Less than half of the children were both correctly and appropriately restrained. Children who were restrained in safety belts appear to be at greater risk of severe injury than are children restrained in safety seats, even though the misuse rate is higher among safety seats. Thirty-five percent of belted children received injuries with an Abbreviated Injury Score (AIS) of 3 or greater compared with twenty percent of children in safety seats. The mean Injury Severity Score (ISS) of belted children was also higher for children in safety seats, although the small sample size results in reduced statistical power. Therefore, the resulting ability to determine the significance of observed differences currently is limited.

Belted children also appear to be at greater risk of injury to the abdomen and lumbar spine. Approximately 34% of the belted children sustained abdominal injury compared to 9%

of the children in safety seats ($p<.05$); additionally, 13% of belted children versus none of the children in safety seats sustained fractures of the lumbar spine ($p<.05$). Lap/shoulder belts do not seem to provide adequate restraint of the upper torso for children aged 8 or younger, as 75% sustained "lap belt complex" injuries while only 1 of 5 older children were so injured.

E. Lower Extremity Injuries

In contrast to recent studies of the biomechanics of crash injuries in adults we found very few fractures of the lower extremities among restrained children. This can be attributed to the fact that the shorter legs of children rarely extended into the toe pan area, the site of numerous intrusion-related injuries in adults. Also, since children do not usually operate automobiles, there is little risk of entanglement of the lower extremities with floor pedals. Among CIREN cases sustaining lower extremity fractures, 70% were involved in frontal crashes and the front right passenger seating position was most common. In regards to restraint use, 43% of the cases with lower extremity fractures were restrained in lap/shoulder belts, 36% were restrained by lap belts only, and 7% were restrained by shoulder belts only. Most of the lower extremity fractures in these children were to the femur, frequently caused by "submarining" of rear seat occupants with loading against the back of the front seats. The instrument panel and door hardware were the next most common contact points for lower extremity fractures.

F. Thoracic Injuries

Children with thoracic trauma were identified from 10,575 injured children (≤15 years) who were consecutively admitted to the CNMC Trauma Center over a 10-year period. Four hundred sixty of these children (4.3%) sustained at least one thoracic injury (667 total thoracic injuries), and of those, 50% required surgical intervention. The mortality rate was 15.6%.

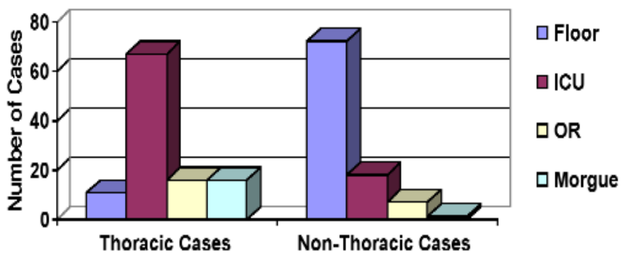
Motor vehicle crashes accounted for the most thoracic injuries (36%), but child abuse and falls accounted for the largest number of fatalities from thoracic injuries (26.9% and 12.8% respectively) compared to 12.4% for motor vehicles crashes. Of the 667 thoracic injuries, pulmonary contusions were the most common (36%), followed by rib fractures (20%), pneumothoraces (16%), and pneumohemothoraces (12%). Pneumothoraces and pulmonary contusions had the highest fatality rate (19% and 16%, respectively) for blunt thoracic injuries; rib fractures and pneumothoraces had the highest fatality rates (14% and 5%, respectively) for penetrating injuries.

In regards to discharge disposition, 50% of thoracic injury cases were discharged home compared to 94% of non-thoracic injury cases, 31% went to a rehabilitation center compared to 4% of those without thoracic injury, and 19% of the cases with thoracic injuries died compared to 2% of those without thoracic injury (Figure 15). Thoracic injuries are also associated with higher Injury Severity Score, a higher median length of stay, and higher acute care costs.

Table 3.
Crash Simulation Scenarios

Scenario #	Seat	Dummy	Usage	Misuse
1	Belt Positioning Booster Seat (No Harness)	6 year old	Correct/Appropriate	
2	3-Point Lap & Shoulder Belt	6 year old	Correct/Inappropriate	
3	3-Point Lap & Shoulder Belt: Lap Belt Only	6 year old	Incorrect/Inappropriate	
4	3-Point Lap & Shoulder Belt: Shoulder Strap Under Arm	6 year old	Incorrect/Inappropriate	
5	Combination Seat (Booster Seat With Harness)	3 year old	Correct/Appropriate	
6	3-Point Lap & Shoulder Belt: Lap Belt Only	3 year old	Incorrect/Inappropriate	
7	Convertible Forward-Facing	12 month old	Correct/Appropriate	Loose belt, loose harness, harness clip location
8	Convertible Rear-Facing	6 month old	Correct/Appropriate	Loose belt, loose harness, harness clip location, seat angle, anchorage height

Figure 15
ED Disposition of Thoracic Cases vs Non-Thoracic Cases



Furthermore, they are associated with lateral impact crashes and crashes with a higher change in velocity.

G. Injury Risks among 2-pt versus 3-pt Restraints

Previous research identified an association of the lap belt complex (abdominal wall contusion, intra-abdominal injury, and lumbar spine fracture) with 2-point lap belt systems. However, CIREN data collected so far has revealed no difference in the risk for serious injury to the head, neck, chest, abdomen, or extremities when children restrained with 2-point belt systems were compared to children restrained with 3-point belt systems. Indices of injury severity (mean Injury Severity Score (ISS), Glascow Coma Score (GCS), Abbreviated Injury Score (AIS), and length of stay) all demonstrated no difference between groups. The 3-point belt, however, was protective for lumbar spinal fractures (OR 0.11, 95% CI=0.01-0.84).

H. Biomechanical Research

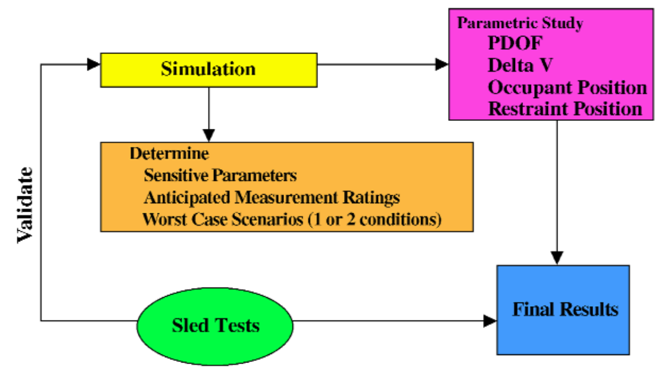
The CNMC CIREN site contracted with the University of Virginia Automobile Safety Laboratory (ASL) in May 2001 to use multi-body computer models to simulate the forces and related moments experienced by child occupants in car crashes. The objectives are as follows:

1. Develop computer models of child occupants involved in automobile crashes.
2. Evaluate child dummy injury values in sled tests.
3. Evaluate the effect of restraint misuse on the forces/moments experienced by children.
4. Develop baseline conditions for use in evaluating future real-world crashes

As of November 2001, most of the sled testing has been completed. The first seven crash simulations (Table 3) were run to determine sensitive occupant response parameters, anticipated response measurement ranges, and worst-case injury scenarios. Specific restraint misuse conditions were modeled to determine the worst-case scenarios. Scenarios with correct usage of child restraint systems were also modeled for comparisons with incorrect and/or inappropriate usage.

A test buck was designed to accommodate rear and front seats and it could be rotated to produce different values of the PDOF (principle direction of force). The buck also accommodated overhead, frontal, and oblique frontal camera views. A total of 23 sled tests, based on the 8 baseline scenarios in Table 3, were conducted. Three digital cameras (1000 frames/second) were used to film each test, and photo targets were placed on all body segments.

Figure 16
Flowchart of Major Phases of Study



The validated MADYMO models were used to perform a series of parametric studies to study the effect of the following variables: principal direction of force (PDOF); Delta V; occupant position; restraint position; and child constitutive data. Various PDOF values added rotational effects to the results. Occupant and restraint positions (incorrect usage) demonstrated which positions place the child at the most risk of injury. There is a lack of constitutive data for children, particularly joint stiffness, which influences dummy designs. The parametric studies in this project allowed for joint stiffness to be varied in the models to show the effect on kinematics, forces, and moments. Final results are still being compiled and analyzed; we are expecting to publish the results in 2002.

V. Outreach Activities

Outreach and education are vital components of injury prevention research. The Children's CIREN team targets physicians, nurses, fire and rescue personnel, law enforcement personnel, allied health and safety professionals as well as the general public.

A. Health Care Provider Education

The Children's National Health Network (CNHN) consists of approximately 550 pediatricians in the Maryland, Virginia, and District of Columbia areas. Since some of these pediatricians are directly housed in the hospital and others are located throughout the community, the CNHN provides a unique target audience when focusing on outreach initiatives. Physicians in this category are easily accessible for focus groups and dissemination of CIREN materials.

Currently, the CNMC CIREN team is developing a child passenger safety poster to be displayed in pediatric offices.

The goal of this project is to ensure that all CNMC affiliated pediatricians have an immediate resource on child passenger safety. In addition, informational seminars and training sessions have been planned to educate pediatric residents on child passenger safety. Similarly, we are training unit nurses on the basics principles of child passenger safety in hopes that they will be able to identify patients on their units in need of proper restraint systems for discharge.

B. Fire & Rescue

We have recently begun to present the CIREN mission to fire & rescue personnel in order to improve triage and field data collection. In April 2001, team members presented CIREN information to emergency personnel at the Emergency Medical Services Care Conference. We are preparing to conduct in-service training to paramedics in the Washington, DC metropolitan area.

C. Law Enforcement

In 1999, CIREN project personnel looked at the accuracy of police crash reports in determining child restraint usage and injury severity. These police crash reports are an important source for obtaining information like restraint usage, occupant seating position, and vehicle ejection, but there are often inaccuracies in these reports. To improve the accuracy of these integral data sources, it is essential to provide adequate training to law enforcement personnel. In efforts to strengthen relations with law enforcement officials and obtain more accurate information on police crash reports, the CIREN team has developed a needs assessment and questionnaire to better understand the role of the police at crash sites and to develop better data collection methods immediately following a crash. This will allow the CIREN team to investigate details of motor vehicle crashes and better assess injuries in children.

D. Safety Advocate Education

One of the most effective ways to disseminate CIREN findings is to "train the trainer." In June 2001, CIREN team members gave a presentation at the International Child Passenger Safety Conference entitled "Pediatric injuries associated with specific restraint misuse". In summary, the most common types of restraint misuse include unanchored safety seats which are associated with blunt force brain injury; child safety seats with loose harness straps associated with ejection-related injuries; lap belt shoulder straps routed underneath the arm associated with thoracic and abdominal injuries; and automatic shoulder belt usage without a manual lap belt associated with thoracic and abdominal injuries. Most Child Passenger Safety technicians are very knowledgeable about safety seat misuse, however, few are aware of the consequences of such misuse. With misuse rates as high as 85 percent, clinicians, child passenger safety technicians, and other specialists must be aware of the patterns of injury associated with the various types of misuse in an effort to provide better care and education to parents; the CIREN program is one of the only programs able to provide such valuable information.

E. National SAFE KIDS Campaign

The National SAFEKIDS Campaign (NSKC) is one of the largest injury prevention programs in the country and, like the CIREN project, it is a program of Children's National Medical Center.

It was launched in 1988 to address what was then a little recognized problem: More children under age 14 were dying from what people call "accidents" (motor vehicle crashes, fires and other injuries) than from any other cause. The Campaign became the first national organization dedicated solely to the prevention of unintentional childhood injury. Its aim is to stimulate changes in attitudes, behavior, and the environment by applying injury prevention strategies that work in the real world – conducting public outreach and awareness campaigns, stimulating hands-on grassroots activity and working to make injury prevention a public policy priority.

Over the years, the NSKC and CIREN have worked in a synergistic fashion to prevent injuries to children in crashes. Since the inception of CIREN, child passenger safety advocates from NSKC have attended case reviews at CNMC to better understand what happens to children in crashes. The real-world biomechanical data from CIREN not only supports many of the NSKC's efforts to promote proper safety seat use but also assists them in identifying new areas to be addressed.

The work of the National SAFE KIDS Campaign provides a vehicle for disseminating CIREN findings directly to parents of children at risk. The Campaign relies on the support of 300 state and local SAFE KIDS coalitions in all 50 states, the District of Columbia and Puerto Rico to reach out to local communities with prevention messages. The coalitions work closely with law enforcement officers, firefighters and paramedics, medical and health professionals, educators, parents, grandparents, businesses, public policy makers and, most importantly, kids.

The National SAFE KIDS Campaign has been instrumental in getting vital safety messages to the public through low-cost or free educational materials including brochures, videos and posters. Thousands of national and local news stories air as a result of the Campaign and its coalitions' media efforts to raise widespread awareness of injury prevention and keep it foremost in the public mind.

F. Emergency Medical Services for Children

EMSC is a national initiative primarily supported and administered by the U.S. Department of Health and Human Services' Health Resources and Services Administration and the U.S. Department of Transportation's

National Highway Traffic Safety Administration. Its goals are to ensure that state-of-the-art emergency medical care is available for all ill or injured children and adolescents; that pediatric services are well integrated into an emergency medical services (EMS) system; and that the entire spectrum of emergency services, including primary prevention of illness and injury, acute care, and rehabilitation, are provided to children and adolescents. Thus, it has initiated hundreds of programs to prevent injuries, and has provided thousands of hours of training to emergency medical technicians, paramedics, and other emergency medical care providers involved in acute care efforts.

Findings of CNMC CIREN research are relevant to many audiences. Engineers and biomechanics researchers have access to all CIREN data via NHTSA. However, to achieve the best injury prevention efforts, CIREN findings must be disseminated to additional audiences that will benefit, namely healthcare providers such as physicians and nurses as well as pre-hospital providers. For paramedics and emergency medical technicians, the emphasis has been on recognizing exceptionally dangerous crash patterns that should increase the level of suspicion for occult injuries. CNMC is uniquely positioned to utilize EMSC avenues to disseminate information to these pre-hospital providers and physicians.

G. Child Safety Seat Distribution Program

One of the concerns in working with the patients enrolled in CIREN is the potential re-use of seats involved in crashes. When a child is discharged from CNMC, quite frequently parents attempt to transport the child home in a car without a child safety seat, with a second-hand safety seat, or in the same safety seat that was used in the crash that injured the child. Although these seats may appear intact, it is difficult to know whether the integrity of the seats has been preserved. Thus, we use a child's admission to CNMC as a "teachable moment" to educate parents on the proper method of restraining their child to prevent future injury.

Last year, our CIREN team applied for funding from Child Health Center Board of CNMC to provide a child safety seat to all in-patient children in need of one. The Child Safety Seat Distribution Program is essentially an outreach program of the CIREN project. The goal of the program is to ensure that all families of children admitted to our trauma center for treatment of injuries from motor vehicle crashes are given the opportunity to be educated in the proper use of child safety seats and are offered the appropriate safety seat for their child prior to discharge. Child safety seats are offered to all children admitted to CNMC with a motor vehicle crash injury regardless of whether or not they meet the criteria for entry into the CIREN study. If a need exists, the appropriate child safety seat will be offered to the family free of charge provided that the parent or guardian receives instruction on how to properly install the seat.

H. Special Needs Restraint Loaner Program

Figure 17
Modified EZ-On Vest

Many children have special transportation needs. For example, babies may be of low birth weight or have medical equipment such as apnea monitors that must travel with them. Similarly, many orthopedic patients in large body casts have special transportation needs that cannot be met by standard car seat or seat belts. Until now, these patients have been placed in "makeshift restraints" or worse yet, no restraint at all. Oftentimes, if a child requires a special needs restraint (Figure 17), it creates financial hardship for families because insurance rarely covers the cost of the restraint. Therefore, a special needs restraint loaner program was implemented by members of our CIREN team to meet the needs of this overlooked patient population.

I. CNMC Child Safety Seat Fitting Station

CNMC has one of the three safety seat fitting stations in the District of Columbia. Parents and visitors of CNMC as well as members of the surrounding community can schedule an appointment Monday-Friday for a seat inspection. NHTSA-certified child passenger safety technicians from the CIREN team will check the child seat for misuse and educate the parents on proper installation and other pertinent child passenger safety issues.

VI. Public Policy Improvements

CIREN data has indirectly impacted on public policy in several ways. In October 2001, CIREN data on the dangers of shield booster seats was presented at the American Academy of Pediatrics (AAP) Conference in San Francisco. Since then, the AAP Section on Injury Prevention & Poison Control has requested additional CIREN data on shield booster seats to support the AAP policy statement.

The adoption, between 1978 and 1985, of child restraint laws in all 50 states and the District of Columbia was a major advancement in child automotive safety, resulting in dramatic reductions in pediatric crash-related injuries. However, because of exemptions in child safety seat laws, many children may legally travel in motor vehicles unrestrained by any protective device. Furthermore, child restraint laws in all states allow for children aged 4 and older to be restrained with adult safety belts. CIREN data has shown that children between 40 and 80 pounds restrained in seatbelts sustain more severe injuries than children restrained in safety seats. Although booster seats are commercially available to provide protection for children between approximately 40 and 80 pounds, few states mandate their use. These findings encouraged NSKC to undertake the most comprehensive review to date of our nation's child occupant protection laws. NSKC measured each state law against a model law that they believe provides a benchmark for every state legislature. The purpose in rating the states is to better inform any efforts to upgrade all state laws over the next five years. With many states placing increased emphasis on the passage of booster seat laws, evidence will be needed to convince constituents that booster seats significantly reduce the risk of injury. It is our hope that as we enroll more booster seat cases, future analysis of CIREN data will yield results that support the model law which requires children under 8 to be properly secured in a safety seat or booster seat, whichever is appropriate for the child's age, weight, and height.

VII. Conclusion

CIREN provides a unique forum for the dynamic interchange among multidisciplinary professionals. Data is used by EMS personnel to triage patients more effectively; medical personnel to study injury patterns and develop better treatment plans; engineers to assess technologies and design safer vehicles/restraint systems; and legislators to support policy recommendations. Thus, this "real world" crash data results in a unique tiered approach to injury prevention.

It is clear that the increased child occupant restraint usage documented over the last 10 years has not eliminated injury to children in crashes. While this risk can never be completely eliminated, the improved design-related performance of safety seats over safety belts, the gains to be made from improved compliance with existing legislation, and the need for better understanding of current restraint usage highlight the 5 "E's" of injury control. We need improved Engineering of restraint systems for children, especially for those who have outgrown booster seats; better Education for parents and children regarding proper restraint usage; increased Enforcement of existing laws coupled with Enactment of stronger laws and regulations; and rigorous Evaluation of these efforts.

Figure 18
CIREN Case After Discharge

Appendix A. Research Publications & Presentations

Publications

Gotschall CS and Eichelberger MR. "Injuries to restrained children in motor vehicle crashes." *Recovery 2001*, in press.

Gotschall CS, Marchant M, Dougherty DJ, Eichelberger MR. "Accuracy of police crash reports in determining child restraint usage and injury severity in the United States." *43rd Annual Proceedings, Association for the Advancement of Automotive Medicine*, 1999.

Gotschall CS, Luchter S, Wing J-S. "Head injuries to motor vehicle occupants aged 0-5 years." *43rd Annual Proceedings, Association for the Advancement of Automotive Medicine*, 1999.

Gotschall CS, Better SI, Bulas D, Eichelberger MR, Bents F, Warner M. "Injuries to children restrained in 2- and 3-point belts." *42nd Annual Proceedings, Association for the Advancement of Automotive Medicine*, 42:29-44, 1998.

Gotschall CS, Dougherty DJ, Eichelberger MR, Bents FD. "Traffic-related injuries to children: Lessons from real world crashes." *42nd Annual Proceedings, Association for the Advancement of Automotive Medicine*, 42:165-178, 1998.

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Gotschall CS, Eichelberger MR, Morrissey JR, Better AL, Reardon J, Bents F. "Nonfatal air bag deployments involving child passengers." *2nd Child Occupant Protection Symposium Proceedings, Society of Automotive Engineers*, Warrendale, PA, 1997; 17-24.

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Gotschall CS, Bents FD, Khaewpong N, Sturm PF, Sivit CJ, Eichelberger MR. "The performance of lap/shoulder belts in restraining children in motor vehicle crashes." In: *Child Occupant Protection (SP-986)*. Warrendale, Pennsylvania: Society of Automotive Engineers 1993.

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Newman K, Bowman LM, Eichelberger MR, Taylor GA, Johnson D, Loe W, Gotschall CS. "The lap belt complex: intestinal and lumbar spine injury in children." *J The Institute for Injury Reduction*, 1991;1:54-61.

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Sivit CJ, Taylor GA, Newman KD, Bulas DI, Gotschall CS, Wright CJ, Eichelberger MR. "Safety belt injuries in children with lap-belt ecchymosis: CT findings of 61 patients." *Amer J Radiology*, 1991;57:111-114.

Newman K, Eichelberger MR, Bowman LM, Taylor GA, Loe W, Gotschall CS. "The lap belt complex: Intestinal and lumbar spine injury in children." *J Trauma*, 1990; 30:1133-1140.

Published Abstracts:

Gotschall CS, Better M, Bents F, Eichelberger MR. "Biomechanics of air bag injuries to children." *J Trauma* (abstract) 1998; 45:192.

Gotschall CS, Better AI, Eichelberger MR. "Differences in injury severity and costs associated with child restraint misuse." *Book of Abstracts*, Volume I, and p. 363. 4th World Conference on Injury Prevention and Control, World Health Organization, May 1998.

Luchter S, Gotschall CS, Walz MC. "Injury patterns experienced by infants and children surviving motor vehicle crashes." *Book of Abstracts*, Volume 1, p. 427. 4th World Conference on Injury Prevention and Control, World Health Organization, May 1998.

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Gotschall CS, Eichelberger MR, Sivit CJ, Sturm PF. "Child booster seats: What works, what doesn't." In: *Abstracts: Workshops, Oral Presentations, Poster Sessions, The Second World Conference on Injury Control*. Atlanta, Georgia: Centers for Disease Control and Prevention 1993; 265-266

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Invited Presentations:

"Pediatric Injuries Associated with Specific Types of Restraint Misuse." International Child Passenger Safety Conference, Annual Meeting, Indianapolis, IN, April 2001.

"The Crash Injury Research & Engineering Network (CIREN)." Emergency Medical Services Care Conference, Greenbelt, MD, April 2001.

"Head injuries to motor vehicle occupants aged 0-5 years" Child Occupant Protection in Motor Vehicle Crashes, Association for the Advancement of Automotive Medicine, Sitges, Spain, 1999.

"Accuracy of police crash reports in determining child restraint usage and injury severity in the United States" Child Occupant Protection in Motor Vehicle Crashes Association for the Advancement of Automotive Medicine, Sitges, Spain, 1999.

"Crash injury findings from merging medical and engineering data." American Public Health Association, Washington, DC, November, 1998.

"Collecting Forensic Data on Children in Crashes," Society of Automotive Engineers TOPTEC, Philadelphia, PA, October, 1998.

"Skull Fractures to Restrained Infants in Motor Vehicle Crashes" 2nd Annual CIREN Research Conference, Ann Arbor, MI, September 1998.

"Differences in injury severity and costs associated with child restraint misuse" 4th World Conference on Injury Prevention and Control, Amsterdam, the Netherlands, May 1998.

"The future of Child Passenger Safety: Restraint-related injuries in children", SAE Government-Industry Meeting, Washington, DC, April, 1998.

"Injuries associated with child safety seat misuse" Lifesavers 16, Cleveland, Ohio, March, 1998.

"Injuries to children resulting from misuse of child restraints" Moving Kids Safely, Tysons Corner, Virginia, 1997.

"Nonfatal air bag deployments involving child passengers" Association for the Advancement of Automotive Medicine, Annual Meeting, Orlando, FL, October 1997.

"Injury patterns associated with child restraint misuse" Association for the Advancement of Automotive Medicine, Annual Meeting, Orlando, FL, October 1997.

"Restraint Related Injuries in Children" Moving Kids Safely 1996, National Highway Traffic Safety Administration, Tyson's Corner, Virginia.

"Children — Vulnerable Road Users" Third International Conference on Injury Prevention and Control, February 1996, Melbourne, Australia.

"Childhood Injury Prevention — Restrained Children in Motor Vehicle Crashes" Lifesavers 12 Symposium, Washington, DC, March 1994.

"Overview of In-depth Accident Investigation — Trauma Team Findings in Late Model Vehicle Collisions" Session Chairperson. Society of Automotive Engineers. Detroit, Michigan, February 1994.

"Biomechanics of Injury to Children Restrained by Safety Belts" Society of Automotive Engineers. Detroit, Michigan, February 1994.

"Crash-related Injuries to Restrained Children Aged 3 to 6 Years" American Public Health Association, San Francisco, California, 1993.

"Are Medicaid-eligible children at greater risk for motor vehicle crash injuries?" Annual Meeting of the American Public Health Association, Washington, DC 1992.

"Control and Prevention of Childhood Motor Vehicle Injury" 2nd National Conference on Injury Control, Denver, Colorado, 1991.

"Patterns of injury in children." American Pediatric Surgical Association, Baltimore, Maryland, May 1989.

CIREN Public Meetings:

"Sport Utility Vehicles and the Pediatric Occupant." CIREN Quarterly Meeting, Detroit, MI. September 6, 2001.

"First There – Be Aware!" CIREN Quarterly Meeting, Washington, DC. June 21, 2001.

"Characteristics of Thoracic Injury in Children." CIREN Quarterly Meeting, Washington, DC. November 30, 2000.

"Predictors of Severe Childhood Injuries in Lateral Impact Crashes." CIREN Quarterly Meeting, Washington, DC. July 21, 2000.

"Lower Extremity Injury Patterns to Restrained Children in Motor Vehicle Crashes." CIREN Quarterly Meeting, Washington, DC. May 5, 2000.

Poster Sessions:

Orzechowski KM, Edgerton EA, Eichelberger MR. "Injury Trends Among Improperly Restrained Booster Seat Age Children Involved in Motor Crashes." American Academy of Pediatrics, Annual Meeting, San Francisco, CA, October 2001.

Gotschall CS, Dougherty DJ, Marchant M, Eichelberger MR. "Accuracy of police crash reports in determining child restraint usage." Partnerships for Health in the New Millennium, Launching Healthy People 2010, Washington, DC, January, 2000.

Luchter S, Gotschall CS, Walz MC. "Injury patterns experienced by infants and children surviving motor vehicle crashes." 4th World Conference on Injury Prevention and Control, Amsterdam, the Netherlands, May 1998.

Gotschall CS, Eichelberger MR, Sivit CJ, Sturm PF. "Child booster seats: What works, what doesn't." Second World Conference on Injury Control. Atlanta, Georgia, 1993.

Gotschall CS, Bents FD, Khaewpong N, Sturm PF, Sivit CJ, Eichelberger MR. "The performance of lap/shoulder belts in restraining children in motor vehicle crashes." Association for the Advancement of Automotive Medicine, Annual meeting. San Antonio, Texas, October 1993.

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University of Maryland
National Study Center for Trauma and EMS

R Adams Cowley Shock Trauma Center

CIREN Program Report

Background

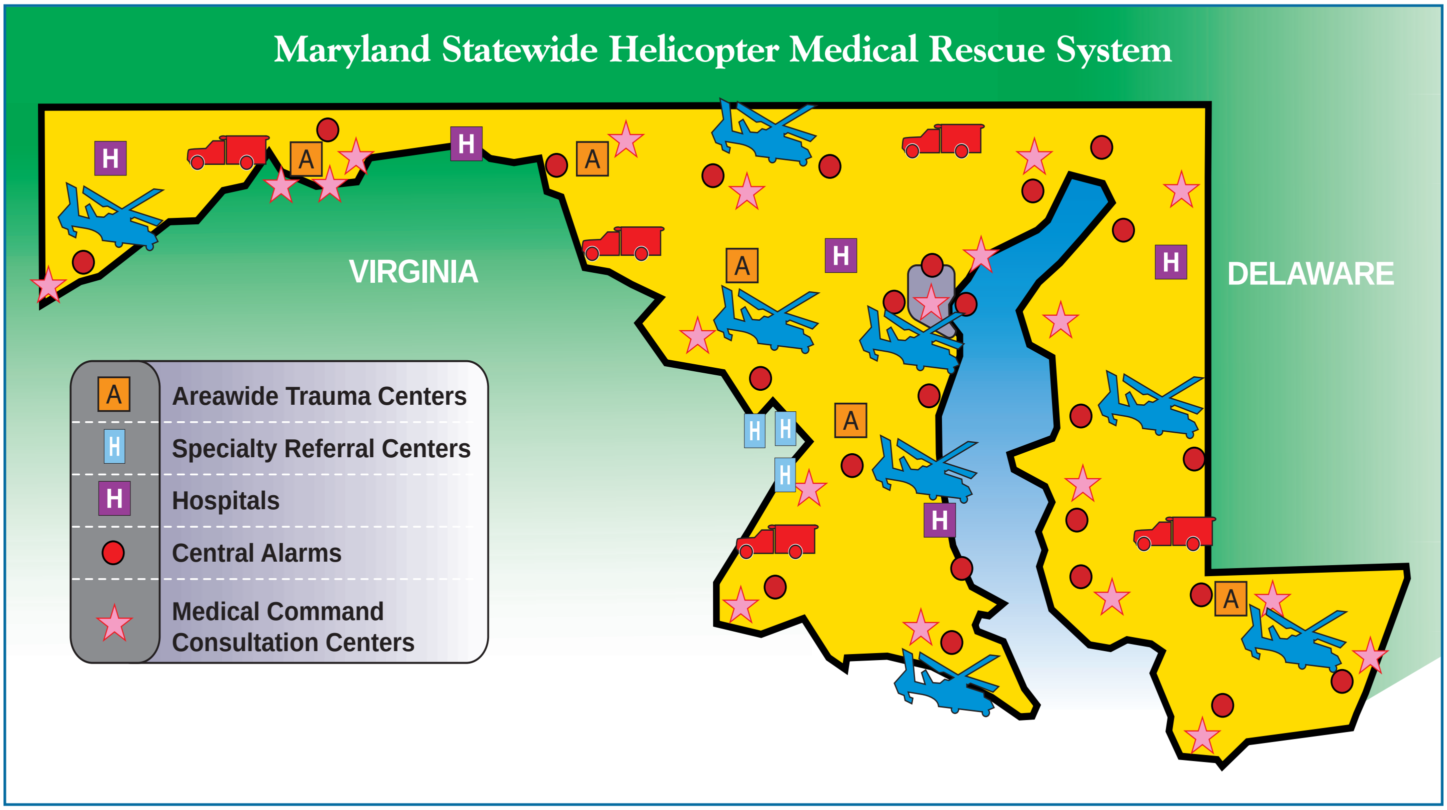
Clinicians and researchers at the National Study Center for Trauma and EMS (NSC) and the R Adams Cowley Shock Trauma Center at the University of Maryland, Baltimore have been investigating motor vehicle crashes and their associated injuries since the late 1980's. The roots of the Crash Injury and Engineering Network (CIREN) at the University of Maryland begin more than a decade ago with the original 'Motor Vehicle Crash Study' under the direction of Dr. John Siegel. Since then, more than 400 crash reconstructions have been performed by the University of Maryland and its partners, more than half as part of the CIREN program. By combining the detailed, multi-disciplinary approach of CIREN with our ongoing work on the epidemiology of motor-vehicle related injury, a clear picture of the causes, costs, and outcomes of these injuries may be obtained. Further, due to our unique statewide study area, the benefit and effectiveness of safety programs may be better quantified and the results serve as a model for other states and regions to implement.

Maryland was the first state in the country to establish a comprehensive, coordinated statewide system for the delivery of emergency health care services and is a recognized national leader in the field. Based on this recognition, the Charles McC. Mathias, Jr. National Study Center for Trauma and Emergency Medical Systems (NSC) was created in 1981 by a United States Senate Joint Resolution. The Center is to conduct trauma-related research with a focus on establishing national policies relating to prevention and treatment of injuries and their causes. The NSC is part of the University of Maryland School of Medicine and serves as the research arm of the Maryland Institute for Emergency Medical Services Systems (MIEMSS) and the R Adams Cowley Shock Trauma Center.

One goal of Maryland's EMS system is to transport patients to the most definitive level of care necessary for treatment of their illness or injury. A key component of this operation is the Med-Evac system which is operated by the Maryland State Police. Eight helicopters are stationed geographically throughout the state (see map below) and are manned by paramedic-certified state troopers. Over the past several years, the Med-Evac program has transported over 10,000 patients from the scene of a critical injury. A large percentage of these injuries result from motor vehicle crashes.

With 7,000 admissions annually, the R Adams Cowley Shock Trauma Center (STC) is the clinical hub of Maryland's system of emergency/ trauma care and thus serves injured citizens statewide. The STC has 24 Intensive Care (ICU), 24 intermediate/step-down, and 34 acute care beds, 10 trauma resuscitation bays, 6 ORs and 7 PACUs. As the lead hospital in Maryland's emergency medical system, the STC is committed to strengthening the total system of care in Maryland, improving clinical outcomes, and promoting injury prevention. The STC also serves as a national and international resource for the development and training of future leaders who will advance the development of trauma and emergency care systems.

In 2000, Maryland's population was 5,296,486, according to the Census Bureau. With 529.1 persons per square land mile, it ranks 6th in population density among the states. Maryland's comprehensive roadway system (29,072 miles) is maintained by the State Highway Administration and 24 political subdivisions and supports in excess of 48 billion annual vehicle miles traveled. There are approximately 3,500,000 licensed motor vehicle drivers and 3,700,000 registered vehicles in Maryland. Three-quarters of those



SYSCOM – the Statewide System Communication Center for Helicopter Medical Rescue

vehicles are passenger cars and 1.5% are motorcycles. Young drivers (ages 15-24) account for roughly 13% of the licensed population while older drivers (ages 65+) account for approximately 11%. While declining slightly since the early 1990's, Maryland's fatality rate has leveled off over the past several years at approximately 12 per 100,000 population (see figure 1). The state's mix of rural highways and urban arteries presents a unique challenge to highway safety and injury control planners, emergency medical providers and clinicians.

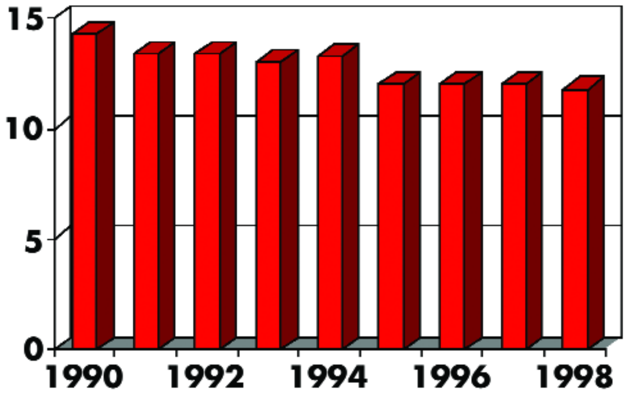
Maryland has a wealth of resources for the study of motor vehicle-related injuries. In addition to a centralized, coordinated EMS system, we have a centralized medical examiner's system, providing data on all vehicular fatalities in the state. From hospital discharge records, we also have access to data on all vehicle occupants who are either admitted to Maryland hospitals or treated in emergency departments and subsequently released. In addition, each of the nine trauma centers provides data to a statewide trauma registry. By comparing the select group of CIREN patients with the information from these larger data sources, it is possible to determine the representativeness of the CIREN population.

Joint and collaborative reviews with other CIREN centers

In an effort to interact and share expertise with other CIREN centers, Maryland CIREN staff have traveled in the past year to the Birmingham and Seattle Centers, where they participated in case reviews. Staff members from Michigan, New Jersey, Children's, Fairfax, and Birmingham have also participated in case reviews at the Study Center. Data from Maryland CIREN cases have also been compiled for use by other centers in the development of presentations and journal articles.

As one of the first CIREN centers, Maryland staff members provided considerable input into the development of the database, serving as one of the alpha test sites. In addition, we have had the opportunity to present the importance of the CIREN program to representatives from Ford and Daimler-Chrysler prior to their participation in the CIREN network.

Figure 1.
Maryland fatality rate per 100,000 population



Staff

One of the strengths of the Maryland CIREN Center is the multidisciplinary nature of the staff.

Patricia C. Dischinger, PhD, Principal Investigator, is an Associate Professor in the Department of Epidemiology at the University of Maryland School of Medicine. Dr. Dischinger has been a researcher at the NSC for 16 years. Much of her research has focused on motor vehicle-related injuries. She is also Principal Investigator for the NHTSA-funded Crash Outcome Data Evaluation System (CODES) project, which examines the epidemiology of motor vehicle-related injuries using available statewide databases, such as police crash reports, ambulance runsheets, and hospital discharge records.

Andrew R. Burgess, MD, Co-Principal Investigator, is Professor of Orthopaedics at the University of Maryland and The Johns Hopkins University and is a world-renowned orthopaedic surgeon with a particular interest in motor vehicle safety. Dr. Burgess has served as Co-Investigator for several transportation safety studies funded by the National Highway Traffic Safety Administration and the Centers for Disease Control in recent years. He regularly participates in case review meetings where he provides unique insight into injury mechanisms and their implications for long-term outcomes. A past president of the Orthopaedic Trauma Association, Dr. Burgess is particularly well known for his expertise in pelvic and leg injuries.

Timothy Kerns, MS, is a database engineer at the NSC and has served as the CIREN project coordinator since 1998.

Kathleen Read, MSW, is a Clinical Social Worker and outcomes researcher. She is responsible for interviewing patients using the SF-36 and other standardized testing instruments.

Shiu M. Ho, MS, has been employed as a data processing system analyst /database engineer for the Charles McC. Mathias, Jr., National Study Center for Trauma and EMS (NSC) since 1990. She is responsible for developing and implementing queries of the CIREN database.

Joseph A. Kufera, M.A., has been employed as a research statistician for the National Study Center since 1993. He is responsible for statistical analysis of the CIREN and outcome databases.

Nafeesa Jawed, MD, is a clinical research associate with the NSC and is responsible for screening and identifying eligible CIREN patients. She is also responsible for entering the medical and clinical variables into the database and for abstracting crash related autopsy reports.

Cynthia Burch recently joined the NSC after earning an MPH degree from the Medical College of Virginia. In addition to her work on other traffic safety projects underway at the NSC, she is responsible for the completeness and quality of the data entered into Baltimore's CIREN database and has been working closely with Dynamic Science and Indiana University.

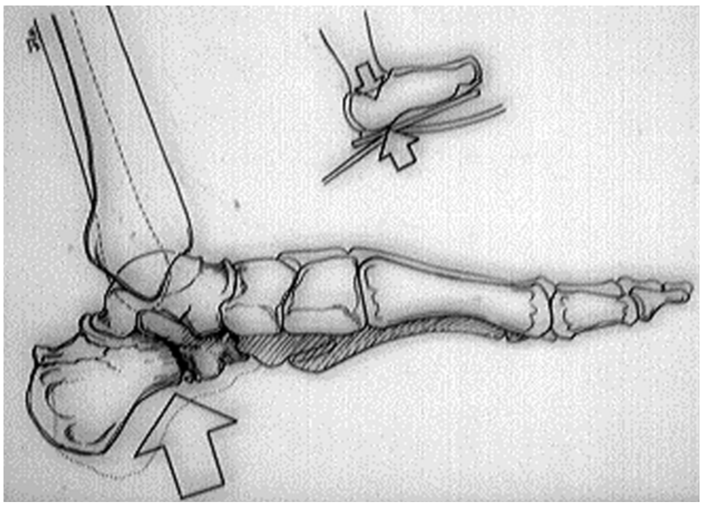
Debra Malone, MD, is the Director of Education and Research for the Coalition for Sustainment of Trauma and Readiness Skills at the trauma center. Dr. Malone frequently attends the case review meetings and contributes her expertise in chest and abdominal injury.

Dynamic Science, Inc., under the direction of Frances Bents, has performed the crash reconstructions for the Baltimore center since the original crash study. In addition to the reconstructions, Dynamic Science is responsible for the input of all crash data and photographs into the CIREN database.

In addition to researchers and physicians from the NSC and STC, our case review meetings are frequently attended by representatives from NHTSA-Washington, NHTSA-Region III, the Office of the Chief Medical Examiner of Maryland, the Maryland Highway Safety Office, and the Maryland State Police Crash Team.

Lower Extremity Injuries

A major focus of research at the Maryland Center has been that of lower extremity injury. These injuries are costly, frequently result in lifetime impairments, and are preventable. Although current information on the biomechanics of these injuries is still insufficient, it is known that they occur most often in frontal and offset frontal collisions, that seatbelts may be ineffective with respect to their prevention, and that vehicular intrusions of the toepan and instrument panel are often, but not always associated with their causation. Many collisions resulting in these injuries occur at delta v's well within the purview of current regulatory standards.



Among patients admitted to trauma centers following motor vehicle crashes, approximately 20% of drivers have at least one lower extremity fracture; the highest incidence rate for a specific fracture is for ankle injuries, with an incidence rate of 5.7%. Surveys suggest that foot and ankle injuries account for 8-12% of all moderate-to-serious injuries sustained by motor vehicle occupants involved in frontal collisions. In a study of the one-year treatment charges for persons hospitalized in Maryland with motor vehicle-related injuries, lower extremity injuries accounted for 40% of the total.

Lower extremity injuries from car crashes tend to be high-energy injuries, which have a poorer prognosis than comparable low-energy injuries caused by slips and falls. Because they involve weight-bearing surfaces and joints, knee and ankle fractures often result in prolonged reductions in mobility. Proximal foot fractures (talus, calcaneus) involve the complex, weight-bearing joints of the ankle and hindfoot and may also result in long-term impairment and disability. However, the disabling nature of these injuries is not reflected by their low scores on injury severity scales which are usually designed to reflect threat to life and not to predict nonfatal outcomes. By collaborating with engineering colleagues at the University of Virginia Auto Safety Lab, we have been able to "recreate" some of these injuries, using experimental techniques such as computer modeling. Also, based on epidemiologic evidence, we were able to show that women had a higher incidence of ankle/foot fracture than did men, and that this was probably a function of driver height. Ankle and foot fractures, which are especially disabling injuries with long-term consequences, frequently result from a combination of axial loading and inversion/eversion forces and are often accompanied by intrusion of the toepan.

With increasing survival rates among drivers in high-speed crashes, due to availability of both seatbelts and airbags, it is anticipated that there will be a relative increase in serious lower extremity injuries among people who would have previously died of multiple trauma, including head, thorax, abdominal, and lower extremity injuries. From in-depth crash reconstruction studies, it is possible to learn more about the mechanism of these injuries, and thus, working with biomechanics experts, address scientific strategies for prevention. As safety equipment and vehicle designs change over time, it will be possible to monitor these changes and their effects on lower extremity injuries, which are currently, with the exception of femur fractures, not influenced by seatbelt use or airbag availability.

Perhaps the value of CIREN is best exemplified by the combination of insight provided by epidemiologists analyzing the incidence of motor vehicle related injuries, surgeons responding with acute and follow-up treatment of those injuries, and social scientists investigating the long-term physical, financial, and psychosocial effects of such injuries.

Long-term consequences of motor vehicle crash injuries

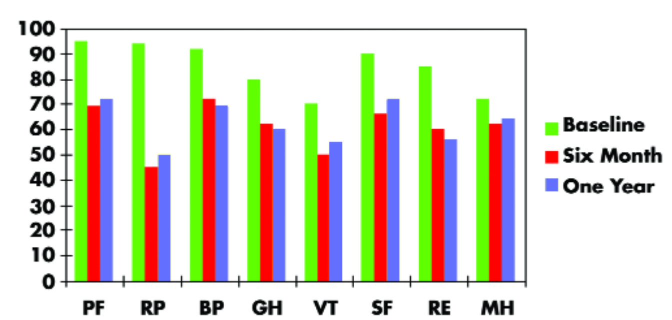
Long-term consequences of motor vehicle crashes include data not only on physical outcomes and functioning, but also the impact of the trauma on the family and society as well as the psychological changes following injury. An important aspect of our research is the in-hospital interview (conducted by our CIREN social worker), and follow-up interviews obtained at 6 and 12 months following hospital discharge. Although the data obtained on the acute injury provides important information about the mechanism of injury, forces, and contact points which resulted in the injury, the true impact of the injury on the trauma patient (both physical and psychosocial) can only be understood from long-term outcome research. NSC staff has donated its expertise in interacting with some of the other centers with regard to the collection and analysis of follow-up data on the human consequences of crash injuries.

Learning about the survivors of trauma and understanding what happens to the people involved in motor vehicle crashes provides an opportunity for injury prevention professionals to partner with survivors and families. Their stories provide an important link to understanding and achieving prevention goals. Physical and or psychological impairments resulting from trauma often take years to overcome. Psychosocial information provides the human dimension of real world crashes when a person is confronted with sudden death, severe injury, and loss. The impact of trauma extends well beyond the crash for the patient, family and society. Since many injuries are costly and disabling, patients often must build a 'bridge' between their pre-crash and post-crash lives. Now, with the increasing availability of airbag restraint systems, more vehicle occupants are able to survive serious crashes. However, many whose lives have been saved are still left with residual injuries.

In Maryland, an in-depth interview with the patient and or family is conducted in the trauma center to establish a pre-injury baseline and history which includes information about their occupation and job, insurance, co-morbidity factors, behavior and risk taking characteristics, the role of alcohol and drugs as well as acute care, rehabilitation and other costs. In addition to an interview, several standardized measurements are utilized, including the SF36 (Short Form Health Survey). Patients are again interviewed at six and twelve months to determine the long term consequences of their injuries. To date, 260 interviews have been conducted.

Below is a graph depicting results of the SF36, which is a health assessment measurement tool that includes one multi-item scale that assesses the following eight health concepts:

1) Physical Functioning (PF): measures limitations in physical activities from bathing and dressing to rigorous activity;
2) Role-Physical(RP): measures physical problems in performing work related activity;
3) Bodily Pain(BP): measures absence of pain;
4) General Health(GH): measures one's beliefs about personal health status;
5) Vitality(VT):measures degree of energy and fatigue;
6) Social Functioning(SF): measures the extent physical or emotional health interferes with social activity;
7) Role-Emotional(RE): measures the extent emotional health interferes with work or daily activity; and
8) Mental Health(MH): measures psychological distress and well-being.



The scale above clearly shows that the CIREN patients demonstrate functional limitations at six and twelve months post-trauma, and that, on average, they have not returned to their pre-injury level of functioning.

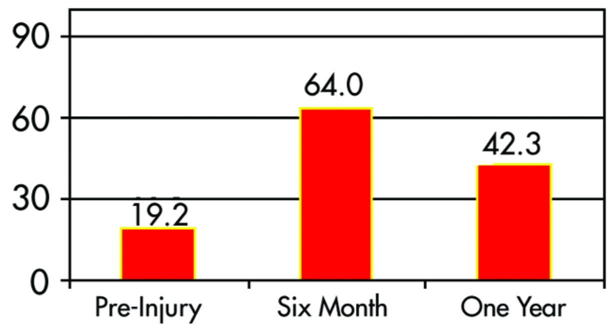
Due to the limitations of the SF36, it is necessary to supplement this tool with other forms of measurement and we have included separate questions in an effort to analyze cognitive function. Unfortunately, there is not one model that exists to assess all the psychosocial outcomes of injury, but clinical experience and methods suggest that many factors are important influences in outcome. Some of the factors considered in our research include pre-existing conditions, socio-economic factors, substance use, depression, post-traumatic stress disorder (PTSD), and litigation. It is also necessary to look at specific groups, for example those with lower extremity injuries, where the long-term consequences may be more costly and disabling. One of the major potential consequences of motor vehicle crashes is the development of post traumatic stress disorder (PTSD). More than 38% of CIREN patients with a lower extremity injury exhibited symptoms consistent with PTSD (see Figure 2).

Figure 2.
Psychosocial Outcomes for Lower Extremity Injury

	Six Month	One Year
	%	%
Behavioral Problem	50.0	23.1
Cognitive Problem	38.5	30.8
Pain Issues	76.9	61.5
Litigation	73.1	46.2
Return to Driving	73.1	88.5
Life Altering Experience	69.2	80.8
Post-traumatic Stress	46.2	38.5

The ways in which people experience a traumatic event and how they are affected by that event varies by individual. There is a range of frequently occurring reactions, most commonly involving physical reactions (nervousness, sleep difficulties, fatigue etc.); mental reactions (fearfulness, loss of control, poor attention, intrusive images etc.); emotional reactions (sadness, grief, guilt, feeling helpless); and behavioral reactions (avoidance, withdrawal, increased irritability, etc.). These reactions depend on one's perception of the loss or threatened loss, physical progress following injury, the fear or horror experienced, the degree that patients hold themselves responsible, prior losses and traumas, current life stressors, and coping patterns. Prior medical and psychosocial history may influence long-term

Figure 3.
Depression/Anxiety



outcomes and psychological well-being. Figure 3 depicts the rates of depression, both pre- and post-crash, among patients with a lower extremity injury. The more we know about such long term outcomes of motor vehicle crashes, the more we learn about how to provide effective treatment programs.

Summary

With the increasing availability of modern occupant restraints including airbags and seatbelts, more drivers survive serious collisions. Thus, it becomes more important to consider the long-term outcomes of these injuries in order to set priorities for injury prevention as in the Haddon Matrix. Lower extremity injuries provide a useful model for this concept as they are usually not life threatening but may have major implications with regard to long-term functioning. Since these injuries occur despite available occupant restraints, new technological advances must be provided in order to prevent these disabling and costly injuries.

Relevant Publications

Brennan P, Dischinger P, Ho S, Kerns T. "Motor vehicle airbags and injury. The Maryland experience." Presented at the 1996 meeting of the Third International Conference on Injury Prevention and Control (Poster).

Crandall JR, Martin PG, Bass CR, Pilkey WD, Dischinger PC, Burgess AR, O'Quinn TD, Schmidhauser CB. "Foot and ankle injury: The roles of driver anthropometry, footwear and pedal control." *40th Proceedings of the Association for the Advancement of Automotive Medicine*, pp 1-18, 1996.

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Presentations

In addition to the annual and quarterly CIREN meetings, the staff of Maryland's CIREN center has been very active in promoting CIREN activities on both a national and local level. Dr. Burgess, in particular, has made numerous presentations to a variety of groups and organizations. The following list is a sample of presentations made by CIREN staff over the past several years.

"Airbags: new dynamics and what they mean to the orthopaedic surgeon." Grand Rounds, Department of Orthopaedic Surgery, The Johns Hopkins Hospital (Baltimore, MD; 2/5/98)

"Motor vehicle crash research (CIREN): airbags and lower extremity injuries." Volunteer Fire Department Convention (White Marsh, MD; 2/25/98)

"Airbags, lower extremity injuries and crash reconstruction." EMS Care '98 (Towson, MD; 5/30/98)

"Crash reconstruction the CIREN experience." Grand Rounds, R Adams Cowley Shock Trauma Center (Baltimore, MD: 10/2/98)

"Airbags – lower extremity injuries (CIREN)." State Farm Insurance Claims Adjusters Meeting (Columbia, MD; 11/19/98)

"Psychosocial characteristics and risk-taking behaviors." Society for Social Work and Research – University of Texas. (Austin, TX; 1/99)

"What we have learned from CIREN crash data." AO North American Visiting Professor. Harborview Medical Center, University of Washington (Seattle, WA: 7/23/99)

"Advanced crash studies, what we have learned from CIREN: relevance to prehospital providers." Western Maryland Trauma Days, Garrett Community College at McHenry (Garrett County, MD; 11/7/99)

"Airbag associated injury patterns." 18th R Adams Cowley National Trauma Symposium (Baltimore, MD; 11/18/99)

"Special Needs of Families of Trauma Victims." American Trauma Society Annual Meeting. (Arlington, VA; 1/00)

"Prehospital providers and mechanism of injury." Kingsville Voluntter Fire Department (Kingsville, MD; 2/5/00)

"Mechanisms of musculoskeletal injury in MVC." Current Controversies and Trends in Orthopaedic Trauma Management (Tucson, AZ; 3/4/00)

"Shock and trauma emergency services and systems for saving lives." Future Urban Transport: Problems and Solutions Interactive Conference (Goteberg, Sweden; 3/30/00)

"Auto crashes and airbags – what we have learned." National Association of Orthopaedic Nurses Conference (Baltimore, MD; 4/12/00)

"CIREN crash reconstruction." EMS Care 2000 (Timonium, MD: 4/30/00)

"CIREN Overview." Special Topics in Trauma Nursing. University of MD School of Nursing (Baltimore, MD 10/00)

"Automotive crashes and the orthopaedic surgeon." Visiting Professor. Case Western Reserve, MetroHealth Medical Center (Cleveland, OH; 11/3/00)

"Clinical and biomechanical aspects of lower extremity injuries, The CIREN Project." 44th Annual STAPP Car Crash Conference (Atlanta, GA); 11/5/00)

"Car crashes: effects on your practice." Visiting Professor. 33rd Annual Peter H. Mack Memorial Lecture, Johns Hopkins University (Baltimore, MD: 11/17/00)

"Blunt cardiac trauma in a restrained driver with an air bag." National Highway Traffic Safety Administration CIREN Public Meeting (Washington, DC; 11/30/00)

"Automobile crashes airbags, and lower extremity injury – what have we learned from the CIREN experience?" Annual George H. Greenstein, MD Lecture, Northwest Medical Center (Randallstown, MD: 12/6/00)

"A multidisciplinary approach to car crash research." University of Maryland School of Social Work. (Baltimore, MD; 12/00)

"Motor vehicle crashes and musculoskeletal injury – effects on the practice of emergency medicine." Emergency Medical Conference, R Adams Cowley Shock Trauma Center (Baltimore, MD; 1/24/01)

"Aging and Driving. Psychosocial Factors and Injury Outcomes of Motor Vehicle Occupants Over 60." AAAM (Detroit, MI; 2/01)

"Clinical lessons learned from CIREN motor vehicle crash reconstruction." Surgical Grand Rounds, Morristown Memorial Hospital (Morristown, NJ; 3/14/01)

"Auto safety – is it really safe to drive?" The CIREN Project. State of the Art in Orthopaedics 2001 (Whistler, British Columbia, CN; 3/20/01)

"Crash reconstruction: lessons for the orthopaedic surgeon from CIREN." Visiting Professor. Louisiana State University (New Orleans, LA; 6/23/01)

"Vehicular crashes – how to keep our patients safe." 2001 Orthopaedic Nursing Update Meeting (Baltimore, MD; 7/20/01)

UMDNJ
University of Medicine & Dentistry of New Jersey

New Jersey Medical School: UMDNJ Crash Injury Research & Engineering Network Center

Introduction:

The first of the programs which now forms the adult component of the CIREN group was established by Dr. John H. Siegel, M.D., FACS, in response to National Highway Traffic Safety Administration (NHTSA) grant request initiated by Dr. Carl Clark in 1988, when Dr. Siegel was the Clinical and Deputy Director of the Maryland Institute for Emergency Medical Services Systems (MIEMSS) in Baltimore. This was a competitive grant and for the first time designed to study injury mechanisms which occurred as a consequence of motor vehicle crashes (MVC) in sedans versus sedans, vans or light pick-up trucks. Prior to this project most of the crash studies had concentrated on mortality, and the difficulty in concentrating on mortality is that it is hard to distinguish a crash whose LETHAL DOSE (LD) is potentially reversible since a fatal crash could have an LD 100, or LD 1000. Obviously, ameliorating the first might be possible, while ameliorating the second would be more difficult.

In addition, it has been clear from studies carried out both by the group at the original center in Baltimore, as well as from the extensive studies by Rice and MacKenzie and by Miller, Luchter and Brinkman and others, that a major cost of motor vehicle crashes is due to injuries and consequent disability. Moreover, studies by MacKenzie, Shapiro and Siegel demonstrated that 54% of the hospitalized cases of trauma in the State of Maryland and 43% of the costs were secondary to injuries of the lower extremity of Grade III or less, not fatal injuries. The cost of motor vehicle crash injury is in the order of $100 billion per year, including the costs of productivity losses, hospitalization, rehabilitation, family support and aid to dependent children.

Therefore, studies directed at examining the exact mechanisms of motor vehicle crash injury to real patients was deemed to be an important consideration, since the engineering groups at NHTSA had concentrated more on fatal injuries and on models using instrumented dummies and staged crashes, which only duplicate a fraction of the mechanisms of real MVC injuries. In response, Dr. Siegel proposed the initial crash injury research center. In this program, information was obtained concerning the importance of lower extremity injuries, the mechanisms of MVC-induced pelvic fractures, and the differing patterns of organ, extremity, and brain injuries identified in frontal versus lateral crashes in passengers and drivers who remained within the motor vehicle. In addition, the role of seat belts in modulating these patterns was delineated. The initial study team which consisted of Dr. John H. Siegel, M.D., as well as Dr. Patricia C. Dischinger, Ph.D., with occasional collaboration with Dr. Ellen MacKenzie, Ph.D., on some of the economic issues, also produced the first group of Proto-CIREN papers listed in the accompanying bibliography.

The New Jersey CIREN Center for Motor Vehicle Crash Research

In 1991, Dr. John H. Siegel, M.D. left the University of Maryland, Maryland Institute for Emergency Medical Services (MIEMSS) to become the Wesley J. Howe Professor of Trauma Surgery, Director of the Trauma Center at UMDNJ-University Hospital, as well as Chairman of the Department of Anatomy, Cell Biology and Injury Sciences at UMDNJ-New Jersey Medical School. This gave him the opportunity to introduce these studies into an academic setting where both basic research and clinical observations could be integrated. In order to facilitate that, a subsection of the original NHTSA Center established at MIEMSS was left under the direction of Dr. Patricia C. Dischinger, Ph.D., which eventually became a second independent adult injury research center under the Principal Co-Investigatorship of Dr. Dischinger and Dr. Andrew R. Burgess, M.D., who had played an important role in some of the early orthopaedic studies with the first proto-CIREN group in Baltimore.

When Dr. Siegel came to the New Jersey Medical School as Wesley J. Howe Professor of Trauma Surgery and Director of the New Jersey Trauma Center, he established it as an American College of Surgeon's (ACS) Level I Trauma Center. During his period of leadership of the New Jersey Medical School University Hospital's Level I Trauma Center (1991-1995), he also worked closely with the New Jersey Regional EMS system to help organize the State into a system of three-Level I Centers and five-Level II Centers in which the Level I Centers had some overall educational responsibility for all the Level II Centers in their specific region. In addition, Dr. Siegel worked closely with the New Jersey State Legislature to create a system of public funding for the State run helicopter emergency retrieval system, consisting of a North Star helicopter based at the New Jersey Medical School, University Hospital, and a South Star helicopter based in Camden, New Jersey. The solution for gaining legislative and executive acquiescence for maintaining this system as a State supported function was to work closely with the Legislature to pass a bill adding one dollar to the motor vehicle registration fee of every vehicle in the State of New Jersey. This annual fund, which amounts to between $7 and $8 million dollars, has served as the major financial underpinning of the system, since it supports maintenance of the helicopters and salaries of the State Police pilots, and the helicopter EMS personnel being provided by each of the two Centers, New Jersey Medical School and the South Jersey Center. The dollar added to the motor vehicle registration fee was considered an "insurance policy" which would guarantee that if a badly injured individual required emergency helicopter transport to one of the Level I or Level II Centers, the EMS helicopter would be immediately available at reasonable cost. The bill passed both houses of the State Legislature overwhelmingly. An added benefit of this statewide system was to induce the Level II Centers to meet Level I Center standards with regard to the maintenance of a qualified trauma surgeon in the hospital at all times, if they were to receive helicopter patients. The advantage of receiving helicopter patients was sufficient to gain voluntary compliance with this requirement, and therefore to thus improve the level and standard of trauma care across the State, by inducing rather than coercing the Level II Centers to upgrade their operation to a clinical level consistent with the Level I Centers, even though they did not necessarily have the education and training programs required to meet ACS Level I status.

In New Jersey, the NHTSA motor vehicle crash research program was continued at both the Baltimore and New Jersey proto-CIREN Centers. The work done initially by Dr. Siegel and Dr. Dischinger also served to assist the organization of other Centers, which now form part of the CIREN network. The Crash Research Program at the Ryder Trauma Center at the University of Miami, Jackson Memorial Hospital, headed by Dr. Jeffrey Augenstein, began shortly after the Baltimore Center was established, and emulated these crash studies. Other Centers have continued to utilize this opportunity, and at the New Jersey CIREN Center we have been visited by teams from the new Centers now established in San Diego, Northern Virginia, Alabama and the University of Michigan.

In 1996, Dr. Ricardo Martinez, M.D., Administrator of NHTSA, directed that all of these individual programs be grouped together in a comprehensive organization known as the Crash Injury Research Engineering Network (CIREN). This was an important step, since it enabled what had been an informal association of programs to begin to coordinate their activities into groups conducting mutually agreed upon participating projects, as well as individual programs which might be confined to a particular Center. For instance, the Children's Hospital Center in Washington, D.C., which was established about the same time as the first MIEMSS Center, concentrated on childhood motor vehicle crash injuries associated with infant-seat restraints. The New Jersey CIREN Center has collaborated with the Baltimore CIREN Center in studies of the patterns of injury as a function of the direction of crash and also in a study of the observations concerning the differences between sedan versus sedan and sedan versus SUV, van or light pick-up truck (SUVT) crashes.

The New Jersey CIREN Center, in addition to participating in these activities, also has an independent project in association with the New Jersey State Regional Medical Examiner serving the area also serviced by the New Jersey Medical School Trauma Center at the University Hospital, to study the mechanism of aortic injuries. This study, in contrast to the previous ones which were confined to survivors of MVC's, involves both fatal as well as surviving aortic injuries in attempt to get a picture of the entire spectrum of the disease and the relative magnitude of the different impact forces, their direction, impact energy characteristics and their impact deceleration velocity (Delta V) with regard to the determinants of the injury itself, as well as the characteristics of the associated pattern of injuries influencing survival. Since this is such a highly fatal disease (> 75% of these patients are dead at the scene of the crash), understanding the mechanisms of their injury may help to significantly increase survival and prevention of this injury.

Overall, the interaction between the various CIREN Centers has been extremely productive and the meetings which are now occurring on a regular basis have advanced considerably in sophistication and collegial interaction. So have the case presentation conferences carried out by interactive computer methodologies developed by the Volpe Center in Boston, Massachusetts, which serves as the main repository for the CIREN database. However, each of the Centers also maintains its own database and at the New Jersey Medical School there is an extensive database which contains somewhat more detail concerning the injury mechanisms than the CIREN database. This NJMS database has been used in some of the studies from this institution on individual projects, both alone and in collaboration with some of the other CIREN Centers.

The present membership of the UMDNJ-New Jersey Medical School CIREN Center:

Principal Investigator: John H. Siegel, M.D., FACS, FCCM, is Wesley J. Howe Professor of Trauma Surgery and Professor and Chair, Department of Anatomy, Cell Biology and Injury Sciences. Dr. Siegel has been involved with the NHTSA motor vehicle crash program since before its incarnation as CIREN, and he is widely recognized as a leading researcher in the field of crash injury.

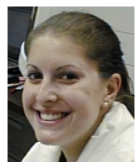
Coordinator: Joyce A. Smith, M.S., has worked with Dr. Siegel since 1985. She has a graduate degree in computer science and experience with research methodology and statistics. She is responsible for overseeing the daily operations of the study, as well as maintaining and upgrading in-house databases.

Medical Research Associate: Dr. Nadia Tenenbaum, M.D., has been with the study since 1999 and is responsible for medical aspects of the study including patient evaluation, follow-up and injury coding. She also works closely with the New Jersey Regional Medical Examiner's Office to obtain detailed autopsy findings on ME MVC crash deaths of interest to the CIREN studies.

Psychosocial Research Associate: Ruth Ross, Ph.D., has been with the study since January 2001. She is involved with conducting psychosocial interviews with patients or family members and in analyzing the resulting data.

EMS Coordinator: Laurie McCammon, B.S., is responsible for all EMS outreach as well as all interactions with police, emergency personnel and tow yard operators. She coordinates vehicle identification and arranges for access to the MVC-involved vehicle(s) by the crash reconstruction team.

Computer Program Manager: Philip Marsh, M.S., has been with the study since 1991 as a mainframe applications developer. He has played a major role in the creation of the computer-based interactive medical graphic which is used by the NJMS center to display and categorize the location and severity of body system injuries and their resuscitative and surgical therapy. These data are also entered as visual images in the CIREN database.


Esther Leibovich

Research Assistants: Esther Leibovich, B.A. (Graduate Student) and Shabana Siddiqi, M.D. are involved in CIREN data entry and coding of injuries.

Crash Reconstruction Team: Frank Costanzo, B.S. and Robert Freeth, B.S., of Accident Cause & Analysis, provide NASS-approved detailed crash reconstruction data which assists Dr. Siegel, Dr. Tenenbaum, Ms. McCammon and Ms. Smith to correctly relate the MVC related injuries to specific crash contact points and intrusions and to the MVC mechanisms.

The New Jersey CIREN Center is based at the NJMS University Hospital and the New Jersey Medical School, which has the Level I Trauma Center designation for the northern New Jersey region. It has a relationship with the Regional Medical Examiner for Essex, Passaic, and Hudson counties. These offices carry out autopsies on all fatal motor vehicle crashes. The New Jersey Medical School is in close proximity to the major North/South and East/West highways, including the New Jersey Turnpike, Federal Interstate Highways #95, #80, #280 and #78, as well as a network of local roads. This area of New Jersey is heavily industrial, but also contains nearly 30% of the New Jersey population and has a wide range of differing cultural and ethnic populations. New Jersey has the widest diversity of ethnic groups of any State in the Union, and therefore, provides a perspective which, reinforced by the demographics of the other CIREN Centers, is useful in understanding the socio-economic and ethnic demography of motor vehicle crashes in the United States. In addition, there is a regional network of Trauma Centers in New Jersey, supported by helicopter, which was organized shortly after Dr. Siegel became Director of the New Jersey Medical School Trauma Center. This gives the NJMS CIREN Center the opportunity to interact with other trauma units in the

State. The elaboration of the present system of Level I and Level II Trauma Centers in New Jersey has also contributed to the substantial reduction in the mortality of motor vehicle crash injury evidenced in the serial FARS reports from 1991 to 2000, due to the facilitation of rapid transport to appropriately staffed and equipped Trauma Centers.

Goals and Mechanisms of the CIREN Group

The activities of the New Jersey CIREN Center have been widely publicized. They have been introduced to the local EMS community through presentations, and they have been communicated to the National Trauma Surgical and Trauma EMS Medical community through widespread publication in peer review journals such as the Journal of Trauma, and through presentations at the national meetings of the American Association for the Surgery of Trauma, the Eastern Association for the Surgery of Trauma and the American Association for Automotive Medicine, among others.

The studies which the CIREN group as a whole are presently carrying out, as well as those specifically being done by the New Jersey CIREN Center, are directed at establishing the specific contributing factors and mechanisms by which injuries occur in motor vehicle crashes. They directly address the patterns of injuries and the relationship of these patient injuries to contacts of the patient's body with deformities and intrusions of the passenger compartment's structure as a function of the direction of crash forces, Impact Energy and Delta V of the crash. They also assess the protective effects of seatbelts, airbags and side-impact and frontal impact crash protection standards. It is envisioned that, from these studies, by examining the mechanisms of specific injuries and injury patterns, models can be created based on real crashes which can be used to help to develop standards by which improvements in motor vehicle safety can be carried out by the various motor vehicle manufacturers. Most important is the fact that the work being done by the CIREN group is presented and discussed in a non-threatening way with consumer representatives as well as with representatives of the motor vehicle manufacturing companies' safety divisions. The CIREN program in its entirety provides a community of common interest, and helps to emphasize not only the public service aspect but equally important, the commercial advantages of improved safety with regard to consumer attractiveness within the highly competitive motor vehicle market.

Issues and Program: New Jersey CIREN Center

The State of New Jersey has approximately 8 million registered vehicles; however, it serves as the transit corridor for virtually all the traffic passing along the northeast corridor to the south. It has been estimated that in a single year, cars equal to 25% of the total registered motor vehicles in the United States pass up and down the New Jersey Turnpike. There is a wide range of types of motor vehicle crashes; however, the New Jersey mortality rate is one of the lowest in the country, in part due to the extensive system of Level I and Level II Trauma Centers linked together by EMS and helicopter transport.

The CIREN Center at the New Jersey Medical School has studied approximately 500 crashes involving motor vehicle drivers and passengers of sedans, SUVs, vans and light pickup trucks. These studies begin with an initial notification of the admission of an MVC patient at the time of admission to the Level I Trauma Center located at University Hospital. If the patient meets the CIREN criteria, the Medical Research Associate contacts the CIREN EMS Coordinator who acquires the police report and the EMS report, and speaks directly with the EMS team in order to determine the circumstances as well as the restraint characteristics of the involved patient. This individual also locates the vehicle for the Crash Reconstruction Team. At the same time, the CIREN Medical Team within the hospital examines the patient, after obtaining an IRB approved informed consent permission, and does a careful evaluation of the patient's injuries, both with regard to reviewing the patient's clinical presentation at the morning trauma conference on the day following admission, as well as obtaining injury photographs where possible and appropriate copies of the radiologic pictures, the operative notes, the clinical course and the discharge summary. The patient is also followed contemporaneously during his or her inpatient hospital course for complications and with regard to the nature and timing of reconstruction procedures.

After the crashed vehicle has been located, with appropriate permission, the Crash Reconstruction Team then examines the vehicle in the light of the injury information and the police and EMS reports, and tries to establish the mechanism of crash and the forces involved. The Delta Vs (instantaneous impact deceleration velocity) are computed from the crash deformities and structural characteristics of the vehicles, and the specific points of contact of the patient with the structures of the passenger compartment are determined and marked and photographed.

In addition, in the last year an experienced psychosocial professional Ph.D. has been employed to interview the patient and the patient's family with regard to those aspects of personality and psychosocial interaction which may have contributed to the crash. This study is a follow up to one done when the Principal Investigator, Dr. Siegel, was at the MIEMSS, which demonstrated that in motor vehicle crashes, especially those of a lateral nature, there was a high incidence of risk-taking behavior amongst younger individuals, which could be predicted by their having a history of having been suspended from High School, as much as 10 years before the motor vehicle crash. These risk taking behaviors were also associated with evidence of family disruption, relationship breakups and/or a previous history of substance abuse. The psychosocial interviewer also participates in the long term follow-up, in order to determine the social and employment impact of the injuries and their recovery duration.

All data collected concerning patient injuries, MVC mechanisms, crash reconstruction, psychosocial interview and follow-up are protected by a Federal Certificate of Confidentiality, which prohibits disclosure of patient identity related to any specific information obtained by this study.

In addition, a specific study is being carried out in association with the New Jersey State Regional Medical Examiner's office for areas served by the New Jersey Medical School Level I Trauma Center. This is directed at the causes and mechanisms of aortic injury and involves the ability to look at the denominator of aortic injury by including all patients with aortic transections, not simply those that reach the hospital alive. The forces involved, and the Delta V at impact, are related to the specific pathology of the injury and the detailed pattern of associated injuries. These are assessed both by direct autopsy examination in the deaths, as well as by surgical, radiographic and physical examinations of those patients who enter the hospital alive, aided by the operative findings and by the nature of the repair or reconstruction procedures done.

Injury Research Findings Summary:

The major contributions of the Principal Investigator and his research team at both sites in studying MVC injuries to adult drivers and front seat passengers who were not ejected, and excluding rollover crashes, have been in the following areas:

First, the proto-CIREN and CIREN studies established the relationship between the type of body component injury and the specific causative impact sites and intrusions of the internal passenger compartment structure of the sedan. Secondly, these studies have examined the differences in these injury patterns with regard to MVCs which occurred due to frontal impacts compared to those caused by lateral impacts. Third, they examined the relative importance of seatbelts and airbags both alone and together with regard to modulating the pattern of injuries in frontal MVCs. In this regard, the two most important findings were:

First, seatbelts prevent MVC ejection, but neither seatbelts nor airbags prevented the severe injuries to the lower extremities, most of which were associated with intrusions of the toepan and foot pedals, or contacts with the instrument panel, especially in shorter and older aged individuals seated close to the steering-wheel.

Second, in frontal crashes the airbag provided a major protective effect, reducing the severity of brain injury. While the incidence of head injury was not reduced, the incidence of severe brain contusion and brain laceration in those patients with a traumatic brain injury (TBI) was markedly and significantly reduced. While in the non-airbag patients with TBI, frontal crashes resulted in a 50% incidence of severe brain injury, (as defined by a Glasgow Coma Scale of 12 or less), in the presence of an airbag, severe brain injury was reduced to 27%, with 73% being mild brain injury (as defined by a Glasgow Coma Scale of 13 or greater). In addition, the incidence of facial fractures and facial lacerations were also markedly and significantly reduced by airbags, either alone or in combination with seatbelts. Thus, the airbag provides an important mechanism for reduction of long term disability, since the more severe brain injuries represent the most difficult rehabilitative problems and can increase the cost of medical care by more than three-fold as demonstrated by previous studies of MVC injury carried out by the Principal Investigator and Dr. Ellen MacKenzie.

Nevertheless, while seatbelts and airbags together do offer the best protection in frontal crashes against brain and face injuries, neither alone nor together have they been demonstrated to prevent severe injuries to the lower extremities. However, in the absence of a seatbelt restraint, there is a tendency for patients with airbags alone to "submarine" during the frontal impact of an MVC by sliding under the steering wheel, and this may increase the incidence of some types of visceral injuries, most notably hepatic injuries.

In lateral crashes, while the seatbelt prevents ejection from the crashed vehicle, the PI's CIREN studies have demonstrated that there is no specific protective effect of the seatbelt in individuals who are not ejected from the vehicle, and that frontal airbags (which were the only ones studied in depth so far) have not been demonstrated to have any clear advantage in a lateral crash in which the occupant is not ejected. Indeed, there is some suggestion that patients held in an erect position by a seat belt in a same-side lateral MVC may be more subject to splenic injury. However, there is not yet a sufficient number of these studies carried out in the presence of side airbags, nor have patients with head airbags been studied extensively, so that the possibility that the increased incidence of severe head injury, lateral compression pelvic fractures and splenic and renal injuries noted to occur in lateral crashes may well be ameliorated by appropriate side airbag construction. This is being investigated and quantified in studies that are in progress.

What is clear, however, is that the vast majority of crashes are not direct frontal impacts, but are rather offset frontal MVCs, and therefore the pattern of injuries and the forces producing them are markedly different depending on both the magnitude of the offset overlap as well as its Principal Direction of Force (PDOF). This is being extensively investigated at the NJMS CIREN Center based on the detailed crash studies presently available. It is hoped that this may allow a more realistic design of NHTSA simulated crashes, as well as a better estimate of the various aspects of motor vehicle construction and improvements in material deformation characteristics which may be protective to the passenger and driver of an off-set frontal MVC.

Another issue which is being investigated at the NJMS CIREN Center, which seems to be quite important, is related to the sex and age of patients. The American population is aging and there is increased incidence of older age women drivers. Our preliminary studies have suggested that this group of patients, who are shorter in stature and thus tend to sit closer to the steering wheel, may have a greater vulnerability not only with regard to airbag related injuries, but also with regard to chest, pelvis and lower extremity injuries by virtue of their extensive tendency toward osteoporosis, especially in the group of late post-menopausal females between 60 and 90 years of age. This is being presently investigated.

There also have been some important incidental findings related to airbag injuries arising from the investigation of MVCs at the NJMS CIREN Center. MVC issues concerning deleterious airbag effects raise questions which can be best explored by collaborative studies by all of the Centers in the larger CIREN group. Studies are needed to define the various precautions and refinements to improve the safety and effectiveness of airbag deployment, not merely by airbag depowering, but also by modulating the power of airbag deployment as a function of the patient's weight and the location of the seat *vis a vis* the steering wheel airbag and by optimizing the location of the airbag deployment sensors and their sensitivity to deployment due to vehicle compartment deformations in non-frontal MVC collisions.

The New Jersey Medical School: CIREN Study Database

Study Inclusion Criteria

- driver or front seat passenger from frontal or lateral MVCs
- no rollovers, no rear end collisions
- no ejection of victim
- must be 16 years of age or older
- all casses obtained after informed consent with Certificate of Confidentiality

Results

- 449 patients were analyzed
  - — 331 frontal crash occupants
    - 174 with airbags
    - 156 no airbags
    - 1 unknown airbag status
  - — 118 lateral crash occupants
- Of the 257 two-car crash occupants
  - — 87 frontal & 33 lateral sedan vs. sedan
  - — 62 frontal & 37 lateral sedan vs. SUVT
  - — 25 frontal & 2 lateral SUVT vs. sedan
  - — 7 frontal & 4 lateral SUVT vs. SUVT

An Example of Recent Studies on the Effect of SUVT vs. Sedan Crashes

In 2000, an extensive statistical evaluation of the cumulative motor vehicle crash data has been analyzed. This consisted of a study of 449 patients of which 331 were frontal crash occupants, 174 in airbag protected crashes and 156 in non-airbag protected crashes. There were also 118 lateral crash occupants. Of the 449 patients, 257 were two-car crash occupants. One hundred twenty (120) of these involved either frontal or lateral sedan vs. sedan crashes, and 99 involved sedans struck by a sport utility vehicle, van or pick-up truck (SUVT). In 27 cases, an SUVT was struck by a sedan, and in 11 cases an SUVT was struck by another SUVT in either a frontal or lateral crash.

The importance of the impact velocity, the instantaneous deceleration velocity (Delta V), on the incidence of traumatic brain injury (TBI) and the Glasgow Coma Scale which measures the severity of the TBI and the mean Injury Severity Score (ISS) are shown in Table 1. These data demonstrate the differences in brain injury severity and Delta V between frontal and lateral crashes. As can be seen in all frontal crashes vs. all lateral crashes, while the Delta V of impact is significantly less in the lateral crashes, there is a higher instance of brain injury and a much more severe magnitude of the brain injury as indicated by a lower GCS score combined with a higher total mean Injury Severity Score (ISS). If one looks only at the two vehicle crashes, a similar pattern is also found with a much higher incidence of brain injury of a greater severity resulting in a higher Injury Severity Score in spite of the lower Delta V.

Table 1: Frontal vs Lateral Crashes

category	N	Mean Delta V (kph)	Brain Injury Incidence (% TBI)	Mean GCS* w TBI	Mean ISS
All Frontal	331	46.6 +/- 1.2	44	11.3+/-0.4	21.7+/-0.9
		+++	++	++	+++
All Lateral	118	37.4 +/- 1.3	58	9.3+/-0.6	28.2+/-1.8
All Frontal 2-vehicle crashes	181	46.7+/-1.5	43	11.4+/-0.5	21.5+/-1.2
		+++	+		+++
All Lateral 2-vehicle crashes	76	36.1+/-1.5	54	9.6+/-0.8	27.6+/-2.2

By t-test or Fisher exact: P-value: '+' < 0.05 '++' < 0.01 '+++' < 0.001

* A normal Glasgow Coma Scale score is 15

Table 2:
Frontal Crashes: Airbags and Seatbelts

category	N	Mean Delta V (kph)	Brain Injury Incidence (% TBI)	Mean GCS* w TBI	Mean ISS
All Frontal No-Airbag	156	47.4+/-1.7	43	10.5+/-0.6	24.6+/-1.1
				+	++
All Frontal Airbag	174	45.9+/-1.6	45	12.1+/-0.5	19.1+/-1.3
Non-Belted Frontal No-Airbag	67	50.4+/-2.8	42	8.9+/-0.9	29.6+/-1.8
				+	+++
Belted Frontal No-Airbag	89	45.3+/-2.0	44	11.6+/-0.7	20.9+/-1.2
Non-Belted Frontal No-Airbag	67	50.4+/-2.8	42	8.9+/-0.9	29.6+/-1.8
				++	+
Non-Belted Frontal Airbag	59	49.5+/-3.2	45	12.5+/-0.8	21.9+/-2.6
Non-Belted Frontal No-Airbag	67	50.4+/-2.8	42	8.9+/-0.9	29.6+/-1.8
				++	+++
Belted Frontal Airbag	116	44.1+/-1.9	45	11.9+/-0.6	17.8+/-1.5

By t-test or Fisher exact: P-value: '+' < 0.05 '++' < 0.01 '+++' < 0.001

* A normal Glasgow Coma Scale score is 15

In Table 2, the effect of seatbelts and airbags are shown. In comparing frontal crashes with or without airbags, it can be seen that, while there was no significant difference in the mean Delta V, nor in the incidence of brain injury, with airbag protection the severity of the brain injury was significantly reduced, as evidenced by a higher GCS score and a lower mean ISS. Comparing seat belts alone, in non-airbag cases a similar pattern is seen with the seat belts also producing an improved Glasgow Coma Score in the brain injured patients and resulting in a lower mean Injury Severity Score. If one compares airbags alone in non-seat belted cases, these data demonstrated also that the airbag resulted in a significantly improved Glasgow Coma Scale in the head injured patients and reduced the total severity of injury with a lower ISS. Finally, comparing the worst case and the best case scenarios, i.e., **neither belts nor airbags**, versus **belts and frontal airbags**, we can see that the effects of these two safety devices are similar, with a significant improvement in the GCS severity of the brain injured patients and a significant, and perhaps even greater reduction in the mean Injury Severity Score with **airbags and belts** together than with either **airbags or belts** alone. These data from real MVC patients quantify in terms of human injuries the results suggested by model studies using Crash Dummies.

Of equal importance is the pattern of injuries, as is shown in Figure 1 comparing frontal crashes with an airbag vs. frontal crashes without an airbag. As can be seen in this detailed pattern figure, the presence of an airbag significantly reduces the incidence of shock and significantly reduces the incidence of severe brain injuries in patients with TBI, defined as GCS≤12. The deployment of airbags in frontal crashes also significantly reduces facial lacerations and facial fractures, reduces the incidence of severe lung injury, reduces the incidence of splenic injury and reduces the incidence of upper and lower extremity fractures. The net result of these reductions in injuries of different parts of the body also reduced the need for extrication of the patient from the crashed vehicle, which decreases the time in the field and facilitates more rapid transport of the patient to a Trauma Center.

Figure 2, which demonstrates a comparison of all frontal cases with all lateral cases shows the greater severity of lateral crash impacts. The incidence of shock, the incidence of total brain injury and the incidence of more severe brain injury (GCS≤12) in TBI are all significantly increased in the lateral crash compared to the frontal crash. While the frontal crashes continue to have a higher incidence of facial lacerations and facial fractures, the lateral crashes have a significantly higher incidence of lung injury, splenic injury, kidney injury and a markedly significant increase in the

Figure 1:
All Frontal Airbag vs All Frontal No Airbag

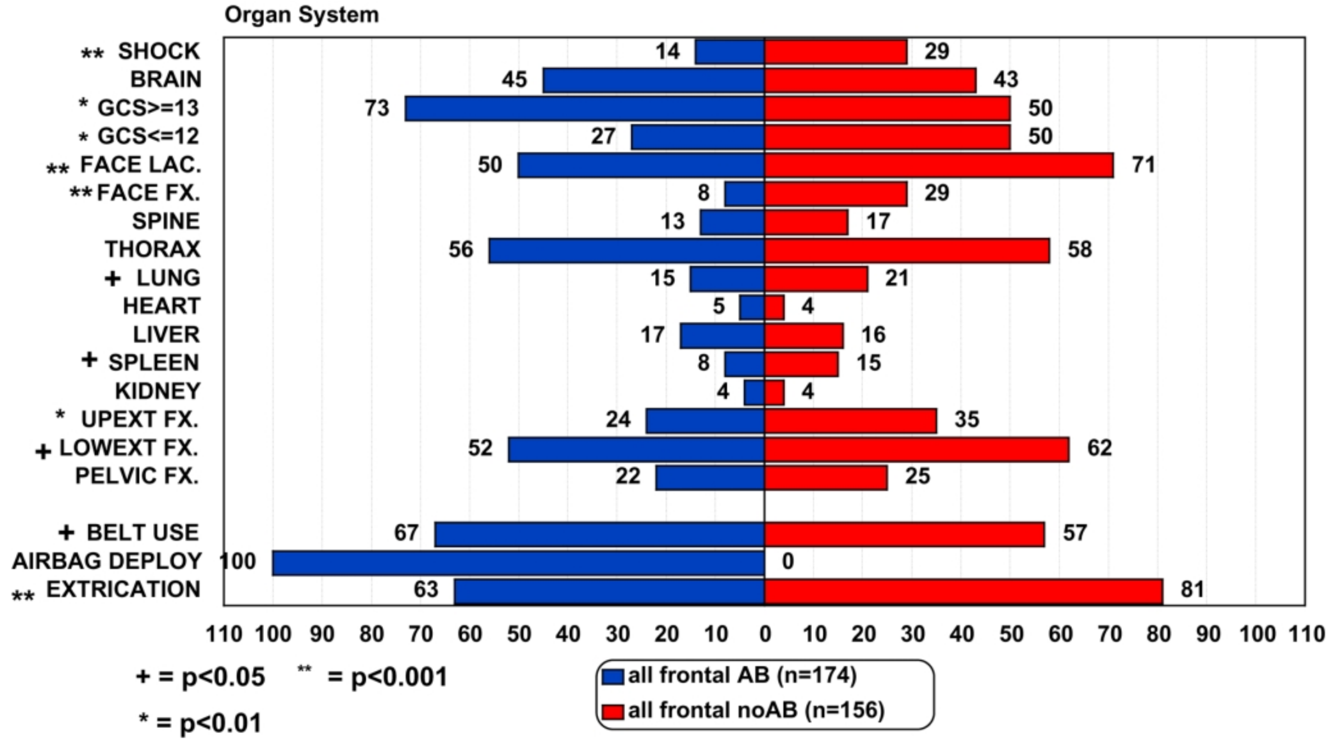
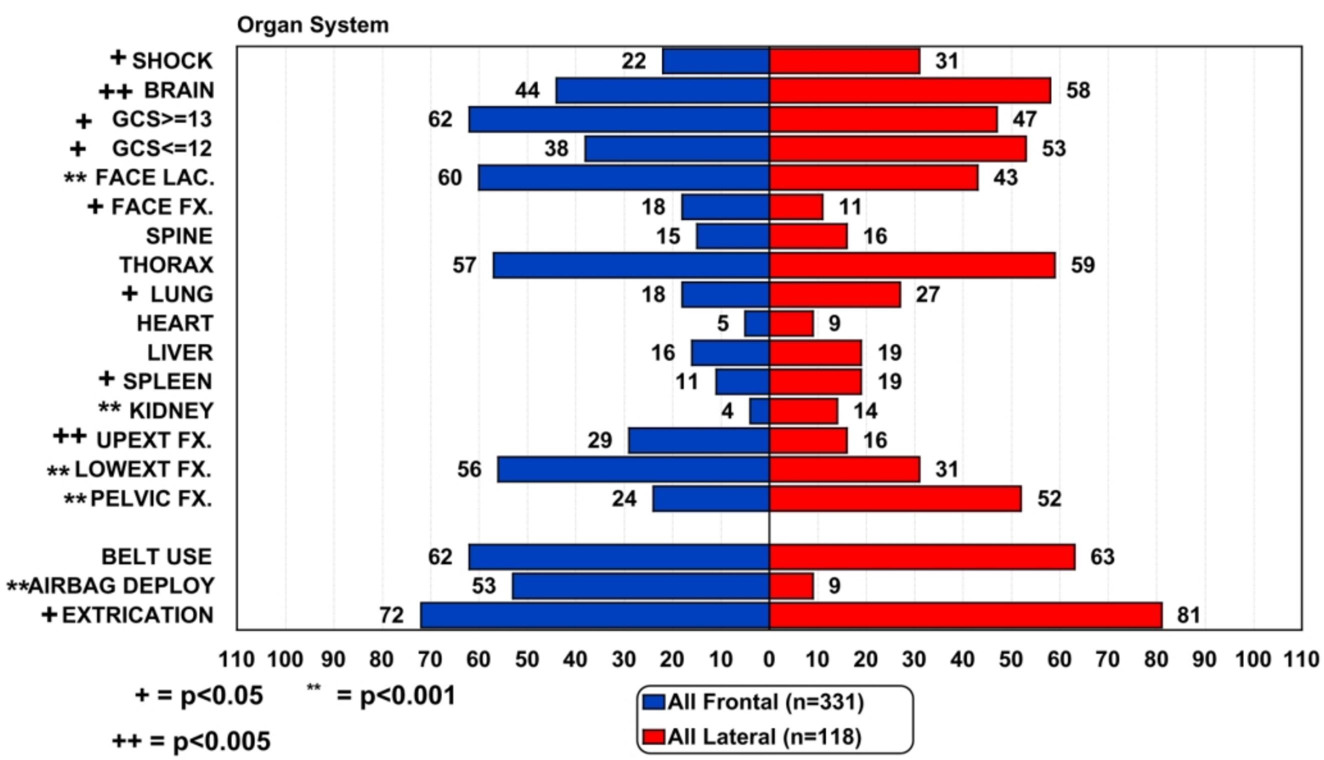


Figure 2:
All Frontal Cases vs All Lateral Cases



incidence of pelvic fractures. This can be seen to occur without difference in the incidence of belt use and to result in the need for a much higher incidence of extrication from the vehicle in lateral crash cases.

The next aspect of the study was to look in detail at the relationship between crashes between occupants of sedans struck by various sizes of SUVT's, comparing independently those sedan occupants involved in frontal crashes versus those involved in lateral crashes. An examination of the frontal crash MVC's can be seen in Figure 3 in which the injury pattern of occupants of a sedan struck by a mid-sized SUVT is compared to the injury pattern of crashes in which the occupant of a sedan is struck by a full-sized SUVT (where the full-sized SUVT is defined as being greater than 1,850 kilograms or 4,070 pounds). As can be seen, as the size and weight of the SUVT striking the sedan in a frontal crash is increased, there is an increased incidence of brain injury, and the brain injuries which result are significantly more severe, as evidenced by a higher percentage of those with a GCS≤12. Facial lacerations are markedly increased in crashes between sedans and full-size SUVTs, but the incidence of lower extremity fractures is actually reduced, suggesting that the size and height of the full-size SUVT shifts the injury pattern toward the head, thus sparing, to some degree, the lower extremities and pelvis.

In lateral crashes when one compares MVCs between sedans struck by a sedan vs. sedans struck by a full-size SUVT (Figure 4), it can be seen that, while the lateral crash pattern already starts as being more severe than the frontal crash, there are similar findings regarding sedan vs. full-size SUVT crashes. In the sedan vs. FSUVT, there was an absolute increase in the percentage of those with brain injury, but, since the percentage of those with GCS≤12 remained unchanged there was thus a greater incidence of more severe brain injury in those with TBI (although these did not reach significance in the number of cases observed). There was also a significantly greater incidence of injuries to the thorax and to the liver. In the lateral crashes, the incidence of lower extremity fractures was significantly lower in the sedan vs. full-size SUVT crash compared to sedan vs. sedan crashes, again suggesting, as in the frontal MVCs, a marked upward shift on the patient's body of the SUVT crash induced injury pattern. This upward shift also occurred in spite of the fact that there was a much higher incidence of belt use in the sedan occupants being struck by a full sized SUVT in a lateral MVC.

Figure 3:
Frontal Sedan/Mid-Size SUVT vs Sedan/Full-Size SUVT

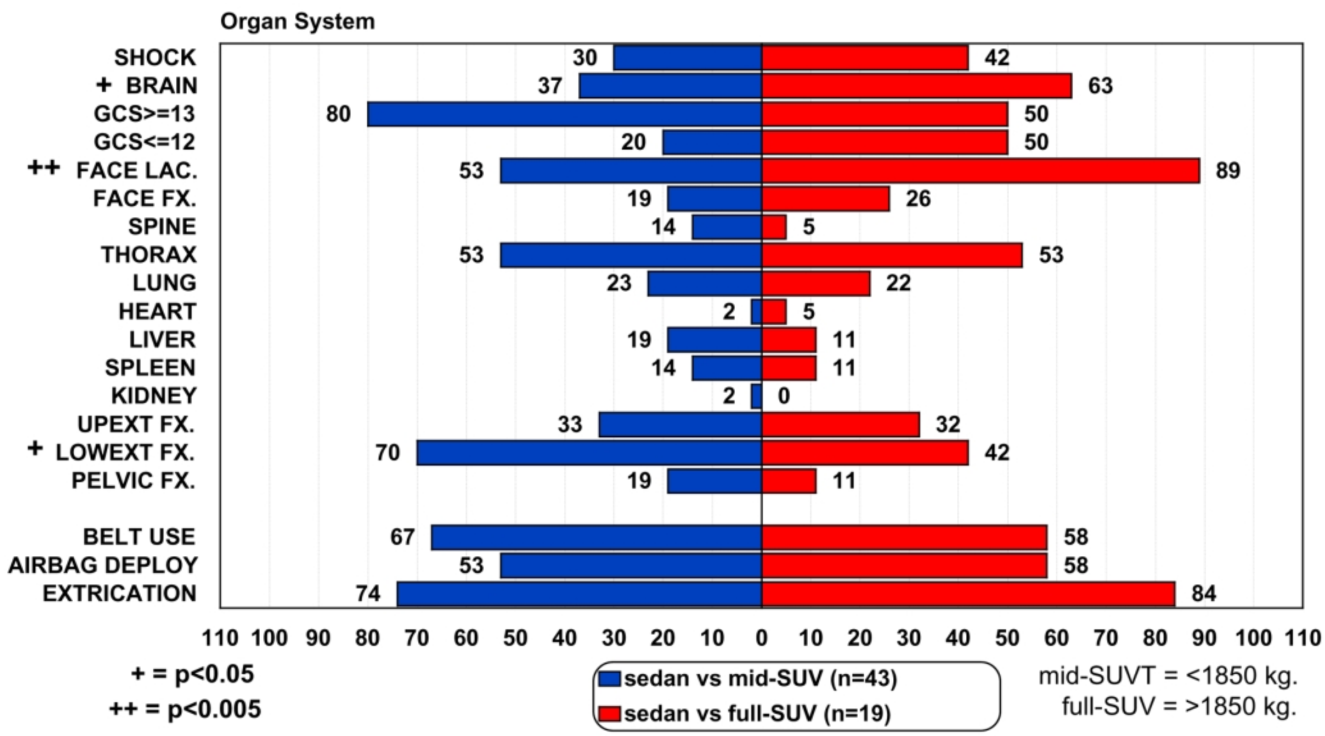
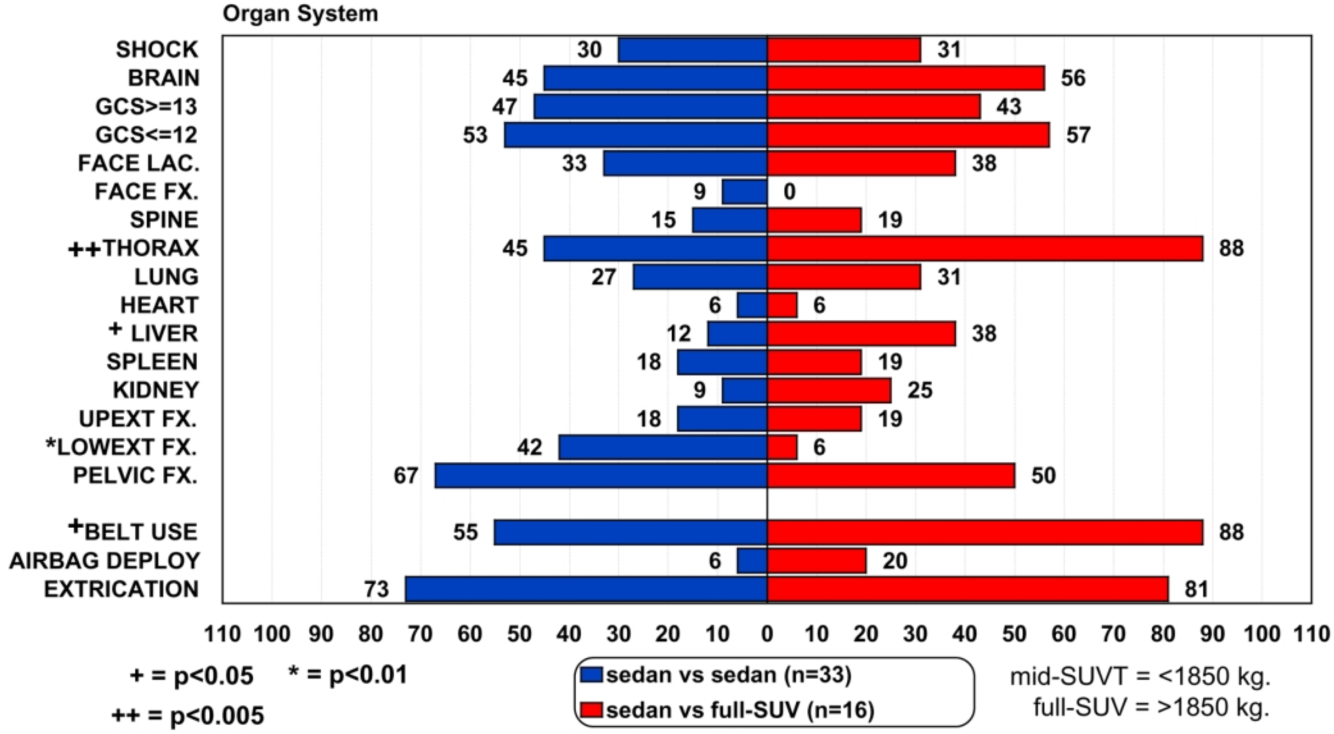


Figure 4:
Lateral Sedan/Sedan vs Sedan/Full-Size SUVT



Structural Factors in SUV, Van and Light Pick-Up Truck (SUVT) Crashes with Sedans that Predispose to the Pattern of Injuries

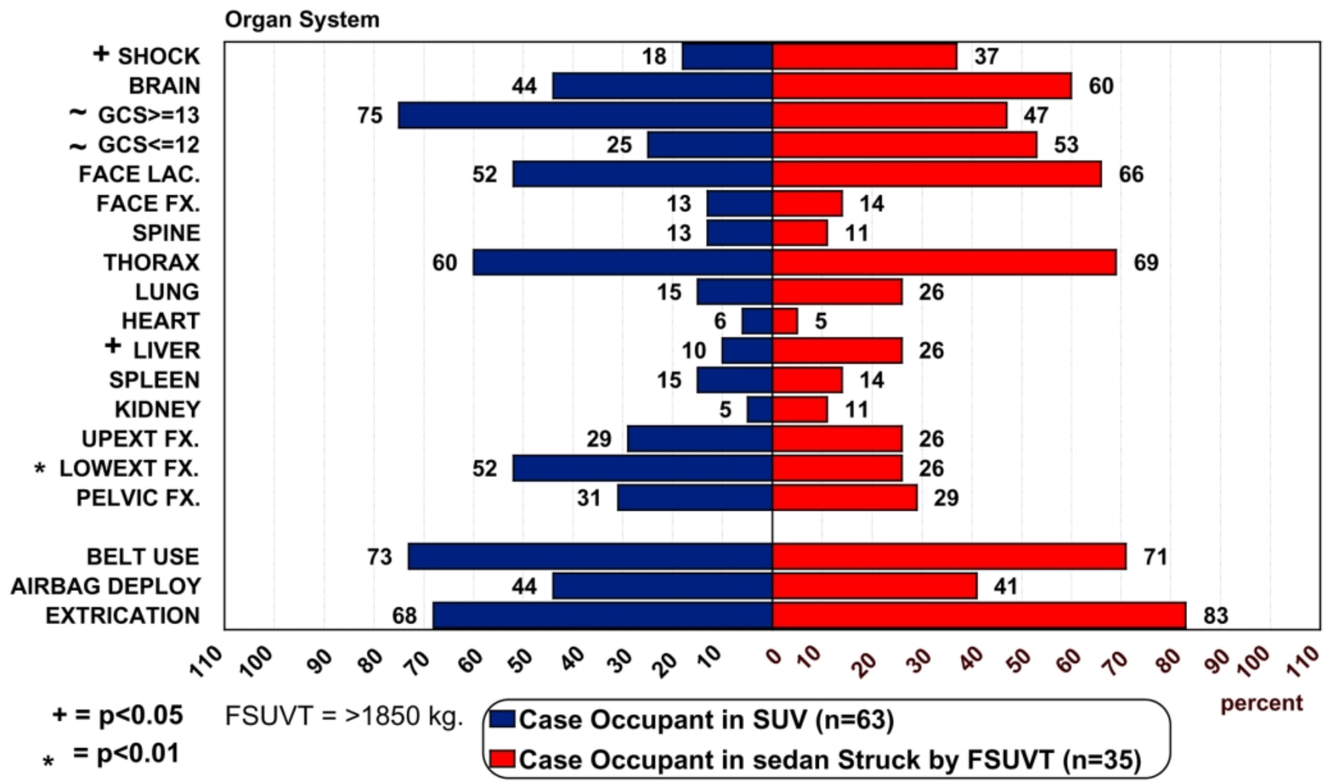
Detailed analysis of the structural data obtained from the crash reconstructions has shown that there are several factors that have significance in determining the alteration and severity in the pattern of injuries sustained by sedan occupants in crashes with SUVs, vans and light trucks (SUVTs). The cases fall into the following categories: those related to **mass** of the vehicles and those related to **structural characteristics**. When one examines crashes between sedans and SUVTs of increasing weight, it can be seen that the **mass excess**, and especially the **ratio of the mass of the striking vehicle to that of the vehicle which was struck**, are significant factors in the pattern of injuries. These are most important in the lateral crash, where the patient has the smallest degree of protection from supplemental devices, such as the collapsible nature of the vehicle structure and the airbags and seatbelts, factors that protect in frontal crashes.

The second structural factor that is important is related to the **excess height of the bumpers** as one goes into the larger class of SUVTs. This is especially evident in lateral crashes, where the bumper of the striking vehicle may hit substantially above the lower body frame of the struck vehicle, therefore allowing for little dissipation of the striking energy by the structural components of the car, but rather permitting the full impact of the crash energy to be directed into the side of the vehicle close to the driver or passenger.

The third factor related to structure is the **hood height excess** which, again, becomes increasingly more significant as the size of the SUVT rises relative to the sedan. This enables the crash force to be impacted in a progressively increasing manner against the upper body: namely, the thorax, head and brain of the driver or passenger in the sedan. This factor is of importance in the increasing frequency and severity of brain injuries in sedan occupants struck by an SUVT in both frontal and lateral crashes. The **width excess**, in which the front of the vehicle is wider in SUVTs than in comparable sedans, allows the impact force to be applied over a larger area, therefore allowing less opportunity for restraint systems, airbags and structural components of the sedans to provide protection to the occupants when struck by an SUVT. **Wheel base excess** is also important in the sense that this reflects the increased size of the full-size SUVT and therefore may add some characteristics in terms of how the forces are dissipated in a SUVT vs sedan crash.

The effect of these structural characteristics in the SUVT can be seen in the difference in the incidence of those injury-producing occupant compartment contacts in sedan occupants struck by an SUVT. When a sedan is struck by

Figure 5:
SUV Injury Comparison: Patient in SUV vs. Patient Struck by FSUVT (frontal or lateral)



another sedan in a frontal crash, the **instrument panel** accounts for the largest percentage of the resulting body injuries. This pattern is even more pronounced in patients protected by an airbag, which tends to provide some degree of protection with regard to face, brain and neck injuries. However, when a sedan is struck by an SUVT, the greater height and weight increase the striking force, overriding the bumper of the sedan, and these factors tend to produce distortions of the passenger compartment. The result is that now there is intrusion of, and body contacts with, the **steering wheel**, the **instrument panel** and the **toepan structures**, all nearly equally responsible for the changing pattern of body and organ injury.

In the lateral sedan vs SUVT crashes, this becomes even more pronounced. In sedan vs sedan lateral crashes, the overwhelming majority of impact sites are secondary to intrusions or contacts with the **door panel structures**. However, when an SUVT strikes a sedan in a lateral crash, both the **door panel structures** and the **A-pillar structures** are now also involved, thus producing a greater incidence of severe head, brain and face injuries.

As a consequence of these differences in structural characteristics and the disparity in mass when a sedan is struck by an SUVT, it is useful to evaluate the difference in the injury pattern of patients in an SUVT struck by a sedan vs. those of patients in a sedan struck by a full-size SUVT (FSUVT). This is shown in Figure 5. Patients in an SUVT struck by a sedan have a significantly lower incidence of shock, of brain injury, and a markedly less severe set of brain injuries (GCS $\geq$ 13) when they do occur, and a significantly lower incidence of liver injuries. Although occupants of SUVTs struck by a sedan have a significantly higher incidence of lower extremity injuries, these, though disabling, are generally not life threatening. Conversely, patients in sedans struck by an SUVT have a significantly higher incidence of shock, and more TBI causing severe brain injuries (GCS $\leq$ 12), 53% vs 25%, as well as a much greater incidence of liver injury as the injury pattern is shifted from the lower extremities upward to the upper abdomen, chest and face and head.

In conclusion, these data provide some insights into the mechanism of real motor vehicle crash injuries provided by the studies from the CIREN program at the New Jersey Medical School. These can be evaluated with regard to their universality through similar studies of the mechanisms of crash injury reconstruction done at the other CIREN Centers. This collaboration and confirmation of real patient injury data obtained on a national basis by the CIREN Centers in different geographic and climatic areas of the country, should enable information to be shared with the motor vehicle manufacturers and consumer advocacy groups in a positive and collegial fashion. This positive interaction will enable improvements in patient safety and a reduction in MVC injuries and disabilities, which are by far the most expensive, and tragically costly in human terms, consequences of motor vehicle crashes.

Bibliography

The attached bibliography contains the relevant MVC related and the NHTSA sponsored papers published by the Principal Investigator both from MIEMSS and from the New Jersey CIREN Centers since the inception of this project. In addition, presentations have been made by the PI on several occasions to the American Association for the Surgery of Trauma, to the Eastern Association for the Surgery of Trauma, to the AAAM, to the New Jersey State Regional Medical Examiner's office as well as to various CIREN meetings held in Washington, D.C. and other locations. In addition, the PI presented a summary of the Preliminary findings of the NJMS CIREN Center aortic disruption study at the combined meeting of the Australian and Canadian Trauma Associations in Sydney, Australia, in March 2001. Earlier presentations to international groups have been made at the Universita Cattolica del Sacro Cuore in Rome, Italy, to the Turkish Surgical Society in Istanbul, Turkey, and in a variety of Post Graduate courses at various universities across the United States and abroad.

The two NHTSA program (now CIREN) Centers that have been led by Dr. Siegel, have been responsible for the education of more than 100 trauma residents and fellows, and many full-time academicians interested in Trauma Surgery, as well as at least five individuals who have become Professors and Chairmen of Departments of Surgery at various institutions across the United States and in prestigious medical schools abroad.

In addition, at the present New Jersey Medical School location of the CIREN Center in the Department of Anatomy, Cell Biology and injury Sciences, there is an active graduate student involved in a study of the differing patterns of injury in full versus offset frontal MVCs, and there have been a number of undergraduate medical students who have participated in the CIREN MVC data acquisition and analysis. Other individuals who have participated in CIREN studies have come from nursing services, EMT, and Paramedic services and presentations have been made to the regional EMS Continuing Education Program.

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William Lehman Injury Research Center

A CIREN CENTER

Prevention, Treatment, Rehabilitation

CIREN Program Report

Overview of a CIREN Center

The William Lehman Injury Research Center (WLIRC) at the University of Miami School of Medicine is uniquely positioned in the Level-1 Ryder Trauma Center at Jackson Memorial Hospital. This CIREN Center's mission is to improve the prevention, treatment and rehabilitation of traumatic injuries resulting from blunt trauma. Fulfillment of this nationally mandated goal of serving as a programmatic research resource is accomplished by our research findings, which will improve quality of trauma care within a cost effective paradigm.

Dr. Jeffrey Augenstein, Professor of Surgery and Director of the Lehman Center describes this environment as a "Living Laboratory for Safety Science". The Lehman Center's goal has been to develop a model for the study of automobile related injuries across the nation. The Lehman Center is one of the founding members of the CIREN network.

The Ryder Trauma Center, which opened in 1992, is a sophisticated facility designed to facilitate the expeditious and continuous care of seriously injured patients from emergency resuscitation to rehabilitation. The design includes the installation of the Lehman Center's comprehensive multimedia clinical information management system (CrashC.A.R.E. Care Administration-Research Education). This integrated system provides real-time data collection, which describes, precisely and completely, the care process from point of impact to clinical outcome for occupants involved in severe frontal, side and rollover automobile crashes.

The goal of the research is to create techniques that could be used in trauma centers throughout the country to better treat injuries occurring in automobile crashes. The study analyzes the epidemiology, acute care, biomechanics and associated rehabilitation of severe automobile injuries. The multidisciplinary research team includes experts in biomechanical engineering, trauma medicine, automobile crash investigation, computer experts, epidemiology and health team members from every discipline.

CIREN Research Group

This multidisciplinary research group obtains detailed information regarding injury and injury mechanism, and applies that knowledge to help reduce highway casualties. The knowledge gained is applied to improve emergency care and treatment of crash victims, to improve the design of safety systems and to enhance the ability to predict crashes most likely to produce severe injuries. The National Crash Analysis Center at the Virginia Campus of the George Washington University has been an important component of this research. As a team, we have developed a national model for combining medical and engineering expertise to help control automobile injury.

With support from the National Highway Traffic Safety Administration, we have made connections with other major automobile safety study centers. We have shared our data with the automobile industry. Presently, we are working with them to determine vehicle characteristics that reduce incompatibility in crashes. In addition, we have presented our findings to other federal agencies involved in automotive safety. Briefings have been provided to the Federal Highway Administration, the Centers for Disease Control and Prevention, the United States Congress, The National Transportation Safety Board and the White House.

William Lehman Injury Research Center –THE CIREN TEAM

Jeffrey S. Augenstein, MD, PhD, FACS: Jeffrey S. Augenstein has been a trauma surgeon at Jackson Memorial Hospital for 21 years and currently directs its Surgical Intensive Care Unit. He is a Professor of Surgery, Director of the William Lehman Injury Research Center, Medical Computer Systems Laboratory and the Surgical Intensive Care Unit at the University of Miami School of Medicine. Dr. Augenstein is currently a fellow and the president-elect of the Association for the Advancement of Automotive Medicine (AAAM).

As the principal investigator of the U.S. Department of Transportation, "Crash Study", Dr. Augenstein has created a national model for research on the prevention and treatment of automobile-related death and injury. With DOT's help, he has led the creation of the state-of-the-art Ryder Trauma Center and developed a computerized information system to address the clinical, research administrative and educational components of trauma. This information system is the backbone of a multidisciplinary research effort addressing the epidemiology and biomechanics of automobile-related injury.

Kennerly H. Digges, PhD: Dr. Digges is the Research Director for the William Lehman Injury Research Center. He leads the investigation of real-world motor vehicle crashes and conducts research to identify injury causation and mechanism and to improve injury recognition.

Professor Digges is also the Director of Biomechanics and Automotive Safety Research, of the National Crash Analysis Center at George Washington University which is funded by FHWA/NHTSA. Dr. Digges' research, both at the Lehman Center and George Washington University, investigates real-world vehicle crashes to determine the performance of safety systems, analyzes crash tests, and conducts analyses of national statistical databases of crash data to assess safety performance of vehicles. The research applies computer modeling of human occupants in motor vehicle crashes and develops greater understanding of the need for improvements in safety and safety equipment.

Dr. Digges retired from NHTSA as a senior executive after thirty-three years of federal service. His work at NHTSA involved improving automotive safety.

Elana Perdeck, BA: Mrs. Perdeck is the Executive Director of the Lehman Center. Mrs. Perdeck is an original team member that brings close to twenty years of administrative and leadership experience to the program. She works closely with the Center's supporters in bringing multi-level funding to the Lehman Center.

James Stratton, BA: Mr. Stratton, director of the crash research program is one of the original members of the Lehman Team. He has been with the Center since it's inception in 1991. Jim brings to the table over 23 years of experience in the crash investigation and analysis field. Prior to joining Lehman, Jim worked as a Team Leader for 14 years with the National Automotive Sampling System.

Martin Singer: Mr. Singer is a crash investigator with the Lehman Team. He brings to the team his experience as a team leader with the National Automotive Sampling System. Mr. Singer joined the Lehman Center in 1997.

Jeffrey Mackinnon: Mr. Mackinnon handles the project coordination for the research study. This position requires him to maintain involvement with crash team members, clinicians, law enforcement, rescue workers, government officials, and case subjects.

Tristram Horton, BS: Mr. Horton is currently a 3rd year Medical Student at the University of Miami School of Medicine. Prior to entering Medical School Mr. Horton was the Project Coordinator for the "Crash Study". One of his major contributions has been establishing the collaboration between the Dade County Medical Examiners Office and the Lehman Center. His interests include traumatic brain injury and the pathological process of injuries to the vertebral column.

Luis Labiste, MD: Dr. Labiste our research associate has completed his medical training. He joined the Lehman team in 1999. His medical expertise has expanded the team's knowledge of injury and injury mechanisms on a continuous basis. Dr. Labiste's extensive knowledge in injury coding is a tremendous asset to the project.

Jerry Phillips: Jerry is one of the newest members of the team. He is responsible for the collection of patient clinical and demographic data. His strong interpersonal skills are a tremendous asset to the team. Creating links between areas is an important part of his role.

Dean Goldberg, DO: Dr. Goldberg the newest member of the team, completed his residency in Michigan's Botsford General Hospital, associated with Michigan State University. He is board eligible in general surgery and has completed his critical care fellowship. He is currently completing a fellowship in trauma at the Ryder Trauma Center. He has a strong interest in automotive medicine and is currently investigating the relationship between pre-hospital and hospital communications as it relates to triage.

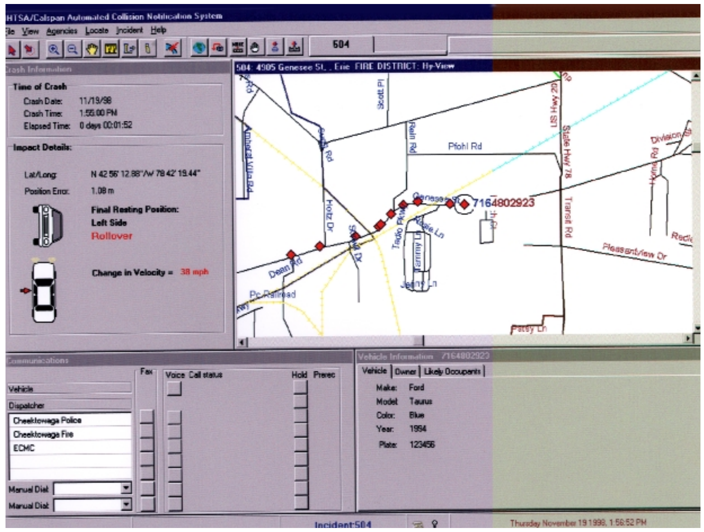
Brian Anderson: Brian is a Battalion Chief with the Miami-Dade Fire Rescue Department and a state certified paramedic. Mr. Anderson brings close to 25 years of fire and rescue experience to the Lehman Center. He joined the Lehman team in 1998 as a liaison between the first-providers and clinical personnel. Brian's interests include vehicle extrication, scene management and injury mechanisms.

CIREN Contributions

By thorough analysis of CIREN and NASS/CDS data, combined with studies of crash tests, cadaver tests and computer modeling of crashes, the Lehman CIREN Center has identified certain crash modes that are likely to produce 'occult' injuries. These occult injuries are sometimes unrecognizable, based on physiological information available to the EMS unit. However, they can be fatal if undetected. EMS care providers that support the Ryder Trauma Center are currently in the process of being trained to recognize high-risk crashes and triage people accordingly. Several papers have been published and presentations made to bring these crash injury models to the attention of the medical community. This research has led to the development of a computer algorithm (URGENCY) that is being used to predict the risk of serious injury and the presence of occult injury, based on information available from the vehicle and from crash scene.

URGENCY

The emergence of Automatic Crash Notification (ACN) systems has provided the ability to rapidly determine the occurrence and location of crashes that are severe enough to deploy the vehicle's air bags. This capability can substantially reduce the time required to rescue injured occupants and initiate medical treatment. However, current ACN systems also present both a need and an opportunity



to use transmitted crash severity information to improve medical treatment by "working smarter" as well as faster. There is a large amount of information about the crash that is currently being measured in conjunction with safety and information systems. The challenge is to identify, prioritize, and communicate the data that is most valuable in saving lives and minimizing the adverse consequences of injuries.

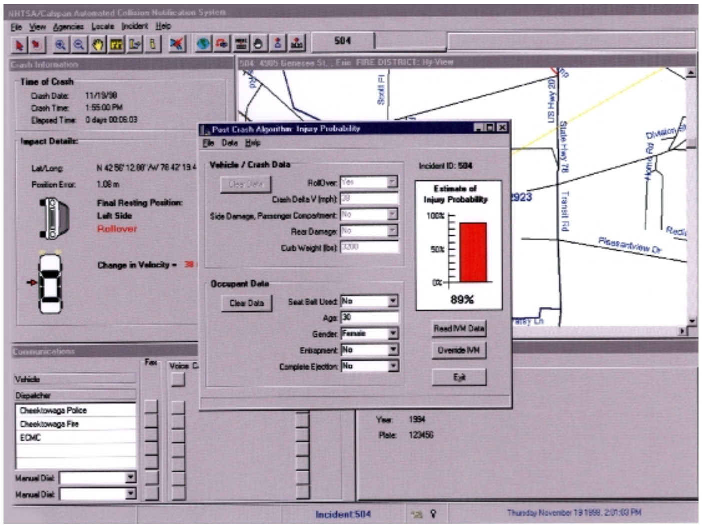
Combining existing crash sensors, global positioning systems, and wireless telephones allows immediate notification of emergency personnel in the event of a crash. The subsequent reduction in response time and dispatch of appropriate rescue personnel would result in improved patient outcome and a reduction in the cost of patient care. The Lehman Center has participated in the development, application, validation, and enhancement of a computer algorithm to identify crash characteristics that have a high risk of producing a serious injury. The algorithm uses data that can be observed at the crash scene, or that can be measured by vehicle sensors. The URGENCY algorithm soon will be employed by EMS services that support the Ryder Trauma

Center. URGENCY software is in the process of being validated and continuously improved through application and analysis at the WLIRC.

The Lehman Center is continuing to make significant achievements in all phases of injury research. Some accomplishments to date are summarized as follows:

Recognition of Crashes With High Risk of Serious Injury

- Developed and applied URGENCY to predict injury risk, based on observed data from the crash site.



- Developed and improved URGENCY to predict injury risk based on observed data available from sensors on-board the vehicle.
- Published validation results for URGENCY in frontal crashes, based on CIREN data.
- Developed and published improvements for the URGENCY algorithm to improve its accuracy.

Side Impact Injuries

- Discovered crash patterns that lead to aortic injuries in side impacts.
- Developed computer modeling to assist in predicting the conditions that cause aortic injury.
- Discovered abdominal injury pattern to belted occupants in far side crashes.
- Published findings of injury patterns in both nearside and far-side impacts.

Occult Injuries

- Discovery of new injury patterns in air bag crashes.
- Development of "Lift and Look " crash scene triage aid for air bag deployments.
- Discovery of pattern of potentially fatal, occult liver injuries in crashes with automatic belts (worn without use of the manual lap belt).
- Development of "Look Beyond The Obvious" national poster campaign to improve practices of triage, diagnoses, and treatment of occult crash injuries.

Air Bag Injuries

- Demonstrated low crash speed deployment problems (unbelted drivers of small stature).
- Identified hip injuries associated with femur abduction in unbelted occupants.
- Documented problems of unbelted occupants missing the air bag.
- Provided extensive data analyses of air bag injuries by linking hospital and National Automotive Sampling System (NASS) files and New Car Assessment Program (NCAP) films.
- Studied the performance of De-powered Air Bags and reported the results to NHTSA, Industry, Congressional and White House Staff, and Consumer Advocates.

Lower Extremity Injuries

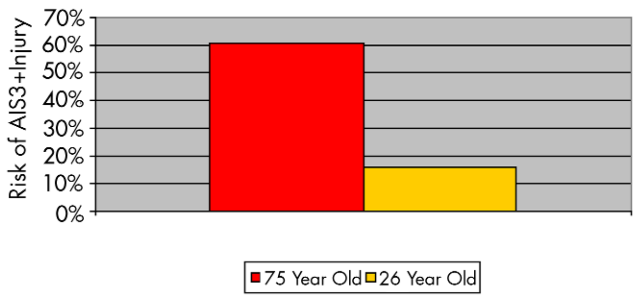
- Advanced the scientific understanding of lower extremity injuries, the associated crash forces, kinematics, and long-term impairment and disability.

- Developed crash investigation methods and techniques to improve the study of injury causation.
- Developed computer reconstruction techniques for determining the conditions that cause lower limb injuries.
- Produced recommendations for improvements in data collection in the National Automotive Sampling System, in hospital studies, in crashes (intrusion measurements) and in dummy instrumentation.

Injuries Among Elderly Occupants

- Identified and quantified the increased risk of injury among elderly occupants.
- Developed and applied the URGENCY algorithm to improve the triage procedures when applied to elderly occupants. This algorithm predicts the increased injury risk of elderly occupants as shown in the Figure below.

Risk of AIS 3+ Injury in 30 mph Frontal Crashes (Based on Urgency Algorithm)



- Discovered elderly occupants are highly susceptible to chest injuries in cars with first generation air bags. Published the findings in SAE 970392, "Heart Injuries Among Restrained Occupants in Frontal Crashes." Elderly occupants protected by airbags were found to be particularly vulnerable to heart injuries.

A New Research Tool

Car crash data can now be collected analyzed and distributed quickly with the use of the CIREN computer system and the Lehman Center's in house computer system.

The Lehman CIREN Center delivered to the National Highway Traffic Safety Administration (NHTSA) the CrashCARE multimedia computer system. Researchers, manufacturers and government agencies, through this Internet-based system, can share automobile crash information. A series of computer-aided instruction modules are almost completed. These are providing training to police; emergency medical services personnel and hospital-based physicians and nurses. By educating these providers on biomechanics, injury mechanisms and proper restraint use, better care can be delivered to injured patients.

Discovered crash patterns that lead to aortic injuries in nearside impacts.

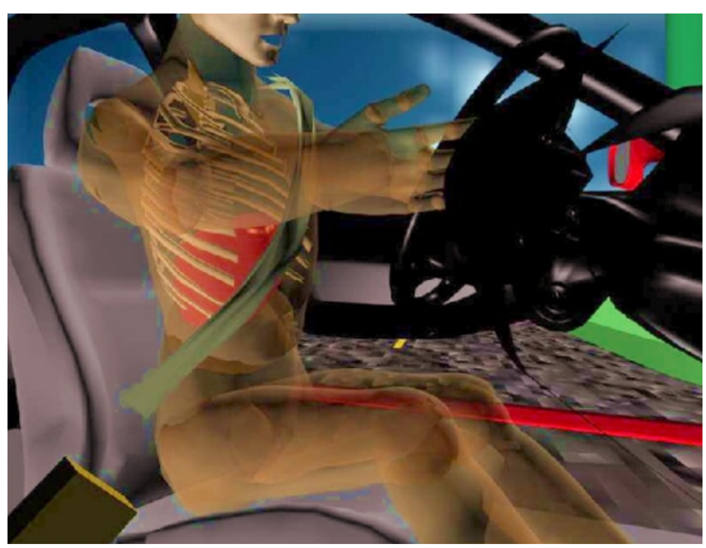
At the March 2000 National Congress of the Society of Automotive Engineers, Drs. Augenstein and Digges won the award for "best technical presentation". The presentation summarized a technical paper entitled "Injury Patterns

in Near-side Collisions", SP –1518, SAE 2000-01-0634, March 2000. The paper documented an analysis of NASS/CDS showing the frequency and severity of injuries in near side crashes by body region and characteristic of the crash. The data indicated that the most life threatening injuries were to the brain, heart and aorta. The paper analyzed cases using WLIRC CIREN data and found that life-threatening injuries to the aorta occurred in a disproportionate number of fatalities. In-depth analysis of the cases suggested that many of these fatalities occurred in crashes that were not excessively severe. Some of those who died showed no indication of severe injury at the scene. Certain characteristics of these crashes were identified and documented. Further research is on going to help predict crash conditions that could produce aortic injury.

Discovered abdominal injury pattern among belted occupants in far side crashes.

This finding was reported at a national conference in October 2000. The technical paper was: "Injuries to Restrained Occupants in Far-Side Collision", 44th Annual Proceedings of the Association for the Advancement of Automotive Medicine, October 2000.

The paper analyzed NASS/CDS 1988-1998 data and found that belted drivers and passengers have different injury



modes in far-side crashes. Head injuries are more prevalent in belted drivers than in belted passengers, representing 40% of the AIS 3+ injuries for drivers, but only 27% for passengers. For belted right front passengers, chest/abdominal injuries account for about 65% of the AIS 3+ injuries compared to 45.5% for drivers.

For belted drivers in far-side crashes, the most harmful injury source is the opposite side of the car (30.5%). The second most harmful injury source is the seat belt (22.6%). Five of thirteen belted far-side occupants in the WLIRC CIREN data had MAIS 3+ injuries from belt contacts. In all belt contact cases, the most seriously injured organ was the liver or spleen. The data indicated that the head contact injuries tended to occur in high severity crashes, while the belt-induced injuries occurred in lower severity crashes. The analysis indentifies opportunities for improvement of occupant restraint systems in far side crashes.

Discovery of a pattern of potentially fatal occult liver injuries in crashes with 2-point automatic belts (worn without use of the manual lap belt).

Reported in (for the second time): "Dummy Measurements of Chest Injuries Induced by Two-Point Belt Systems", 44th *Annual Proceedings of the Association for the Advancement of Automotive Medicine*, October 2000.

In the WLIRC CIREN database, there were 48 cases of drivers protected only by a shoulder belt. Fifty percent of these drivers suffered liver lacerations. Further study showed that 22 of the crashes involved damage to the right front of the vehicle. Among the drivers in vehicles with right front damage, 92% sustained injuries to the liver. This observation indicated that 2-point belts were most likely to produce liver injuries in low severity frontal collisions when the direction of force is 1 to 2 o'clock in relation to the vehicle.

An analysis of NASS for the years 1988-95 indicated that liver injuries constitute about 0 .5% of the injuries suffered by drivers who are in tow-away crashes. NASS data showed that the risk of chest injury is more likely among drivers with automatic shoulder belts than drivers with 3-point manual belts. The crash test dummies as used in the NCAP program, did not distinguish differences in chest injury measures for the 2-point and 3-point belt systems. Finite element computer modeling (FEM) demonstrated that the high deflection of the right lower rib predicts the liver injuries in the 1 o'clock crashes. These higher deflections were less apparent at the location of the center chest deflection measurement device on the Hybrid III dummy. Consequently, the existing dummy is unlikely to predict the liver injuries produced by belt loading of the lower ribs and abdomen. The WLIRC CIREN crash data and the FEM model indicate that liver injuries to the driver are more likely to occur when the crash vector contains a lateral component that directs the driver toward the centerline of the vehicle.

Failure to wear the lap belt increases the loading of the shoulder belt on the body surface overlying the liver, producing a characteristic "seat belt sign" superficial skin abrasion. This condition provides an initial clue for emergency care providers to look for liver injuries. A second clue is principal damage to the right front of the vehicle in which the driver was injured. In these types of crashes, liver injuries can occur at a relatively low amount of vehicle damage. As the extent of damage increases, damage to the entire front of the vehicle is an additional clue. Triage criteria using these findings have been implemented at the WLIRC with positive results.

Recognition of Crashes with High Risk of Serious Injury

Developed and applied the URGENCY algorithm to predict injury risk, based on observed data from the crash site.

These initial results were published in: "Development and Validation of the Urgency Algorithm to Predict Compelling Injuries", Paper Number 350, ESV Conference, June 2001.

A study of WLIRC CIREN cases confirmed that URGENCY can differentiate crashes with serious injuries from non-serious injury crashes. With regard to the analysis of MAIS 3+ injuries, the algorithm had a positive predictive value of 96% and a negative predictive value of 63%. The majority of injuries not predicted involved injuries in multiple impact crashes, pole crashes or air bag deployment injuries. Adjustments in the algorithm to introduce predictors for pole crashes and multiple impacts significantly improved the prediction capabilities. Further improvements in the algorithm are necessary to predict air bag deployment related injuries associated with close-in occupants. To predict these injuries factors such as crash pulse, air bag deployment time, and occupant/seat position may be required. Overall, the predictive capability of the URGENCY algorithm was considered to be satisfactory for use as an aid in identifying occult injuries among occupants that do not meet physiological triage criteria at the crash scene. Additional refinements identified by this study are being incorporated.

Studied the performance of De-powered Air Bags and reported the results to NHTSA, Industry, Consumer Advocates, and Congressional and House Staff.

Distributed a paper entitled: "Performance of Depowered Air Bags in Real World Crashes"

During the period 1995 through 1999, WLIRC-CIREN team collected crash and injury data on 135 drivers and 29 right front passengers in frontal crashes with air bag deployment. Among these were sixteen cases with depowered air bags. This paper compares the crash characteristics for injured occupants in vehicles with 1st generation and depowered air bags.

The population with 1st generation air bags contains unexpected fatalities among children and older occupants as well as fatalities at low delta-V's. To date, these populations are absent among the fatally injured occupants of vehicles with depowered air bags. Three of four fatalities in depowered cases occurred in crashes that were so severe that the occupant compartment was destroyed.

The depowered cases include both belted and unbelted survivors at crash severities above 40 mph delta-V. The maximum injury in these 40+ mph cases was AIS 3 with no evidence of unsatisfactory air bag performance.

However, serious internal chest injuries were observed in two cases. The cases involved unrestrained drivers with crash severities of 19 and 24 mph. These cases suggest the need for continued refinement of depowered air bag performance for unrestrained drivers at crash severities below 25 mph.

A Scenario of the Near Future

A car crashes. The car automatically calls for emergency medical assistance. The Automatic Crash Notification system in the car reports: the location of the crash in global positioning coordinates; that the crash had a 12:00 direction of force and a total instantaneous change of velocity of 36 mi. per hour; that the frontal crash appeared to be into a narrow object; that the frontal air bags had deployed; and that no passenger was wearing the available seat belts. In addition, the driver's smart key identified the individual as a 62 year-old male with type 2 diabetes, taking the medication Digoxin and having allergies to iodine and penicillin. The data are instantly, and automatically, used in a computer program to calculate an URGENCY rating for this crash. The URGENCY rating provides the emergency medical system with an instant probability of a serious injury being present in the crash. URGENCY ratings are used to dispatch an appropriate level of emergency rescue resources. And personnel at the trauma center are notified.

A trauma surgeon communicates with the paramedics at the scene of the car crash. Information about the crash and the occupants, including pictures, is transmitted wirelessly to the surgeon's pocket PC.

Critical pieces of information are continuously entered into the URGENCY triage algorithm automatically via wireless or manually. The driver had physiologically stable vital signs and had no complaints of pain. However, the triage algorithm suggested that this individual had a more than 80% probability of sustaining a life-threatening injury. The computer recommended evaluation for a thoracic aortic tear and heart rupture. The physician and paramedics had received online training on mechanisms of automobile crash injury. Thus, there was little discussion about transferring this apparently uninjured person to the trauma center. The patient deteriorated shortly after arriving at the hospital. An echocardiogram revealed fluid around the heart, suggesting a cardiac injury. The patient was rushed to the operating room wherein a small laceration of the right ventricle was repaired.

The residents and fellow on their respective hand-held computers created the operative report and intensive care unit orders. Most of the operative report was created by picking options from menus optimized for surgery of the heart. The surgeon could have dictated parts of the report into the hand-held device. A drawing of the surgery was completed utilizing anatomic images available on the hand-held computer. In this case the entire operative description, including the surgeon's sketch and intra-operative photographs were available to the intensive care staff. The attending surgeon, through the hand held computer, entered all the professional billing codes. Of course, the various documents including the operative report, the intensive care orders, and the billing voucher were electronically sent to the hospital's electronic medical record as they were created.

The surgeon reviewed the case with the staff later that day. A teaching module on the hand-held computer provided animations that explained the mechanism of injury.

In the intensive care unit the physicians and nurses used their hand-held computers to write notes and manage orders. For example, a rules' system supported a first-year resident as he attempted to choose an antibiotic for a newly identified pseudomonas pneumonia. The software facilitated the dosing schedule for the aminoglycoside in this patient with reduced kidney function. The young physicians were instructed that the supporting evidence for the treatment regimen could be downloaded to their hand-held computers. Additionally, a series of lectures were available for viewing on the Web and an abbreviated version could also be downloaded to the hand-held devices.

The heart-injured patient recovered and received follow-up care initially on the floor unit and then as an outpatient. As the attending surgeon saw this patient and others on the floor she had access to all relevant data on the hand-held, and wrote all orders and notes using that device. Although a flow sheet and graphical representation of data were available on the small computer, the attending chose to have some of the complex flow sheets printed out.

The hand-held computer also provided the well-accepted functions of e-mail, pager messaging and scheduling. Because all of these exchanges occur in a wireless, instantaneous mode, communication and scheduling have been greatly facilitated in terms of time and usefulness of information for improved quality of care.

This scenario is possible in the near future at the University of Miami/Jackson Memorial Medical Center. The CARE system includes virtually the entire infrastructure of information to support the various applications. The CARE development team has created a prototype pocket PC system that communicates, in a secure fashion utilizing wireless, infrared and desktop synchronization techniques, with the main system. The necessary additional software could be rapidly developed and/or licensed. For example, the pharmaceutical rules' system would be licensed. The team has more than 10 years of experience in utilizing local area wireless networks. In addition, relationships have been developed with wide area network wireless providers and infrared network providers.

Recent Presentations:

"Real World Performance of Depowered Air Bags." Presentation to NHTSA, DOT, Washington, DC., April 5, 2000.

"Computer Reconstruction of Motor Vehicle Crashes to Understand Mechanisms of Lower Limb Injuries." Presentation to Honda Motor Company, Miami, FL, April 17, 2000; repeated in Utsunomiya, Japan, May 12, 2000.

"Computer Reconstruction of Motor Vehicle Crashes." Presentation at NHTSA, DoT for National Meeting of CIREN, Washington, DC, May 5, 2000.

"Performance of Depowered Air Bags." Presentation to Alliance of Automobile Manufacturers, Detroit, November 14, 2000.

"Patterns of Injuries in Side Impact Crashes." Presentation to Alliance of Automobile Manufacturers, Detroit, November 14, 2000.

"Injury Patterns in Offset-frontal Crashes." Presentation at NHTSA, DOT, for National Meeting of CIREN, Washington, DC, March 16, 2001.

"Youth vs. Maturity." Presentation at SAE TOPTEC February, 14, 2001.

"Injury Patterns in Near-side Crashes." Presentation at NHTSA, DOT, for National Meeting of CIREN, Washington, DC, May 15, 2001.

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Harborview Injury Prevention & Research Center at University of Washington

CIREN Program Report

Seattle CIREN Team: Setting

The Seattle CIREN team is based at the Harborview Injury Prevention and Research Center (HIPRC). HIPRC was founded in 1985 by two pediatricians, Dr. Frederick Rivara and Dr. Abraham Bergman. Since that time, it has grown to be one of the leading injury prevention centers in the United States and, in fact, the entire world. More than 80 people work at the HIPRC including research workers, study nurses, graduate students, and University of Washington faculty from several departments including surgery, orthopedics, pediatrics, emergency medicine, epidemiology, biomechanics, and other fields. The Center has numerous contacts with others involved in injury prevention and safety including members of the lay public as well as non-governmental organizations and various branches of the government. These contacts include those in Seattle, Washington state, elsewhere in the Northwest, throughout the United States, and internationally.

The Seattle CIREN team was started in 1996. Several unique features add to the strength of the CIREN efforts in Seattle. These include the association of the HIPRC with the adjacent Harborview Medical Center. Harborview is one of the leading trauma centers in the entire United States. It is the only Level 1 trauma center serving the states of Montana, Idaho, Washington, and Alaska, which together account for one-fourth of the land mass of the United States. Harborview has over 5,000 trauma admissions per year. The admissions come from throughout this four-state area. Hence, the Seattle CIREN team is in contact with the cutting edge of clinical trauma surgery.

Through its connections with the HIPRC, the Seattle CIREN team also benefits from the expertise of faculty members in several different departments of the University of Washington. For example, this includes the School of Medicine with its Departments of Surgery and Pediatrics, which has assisted with understanding anatomic injury patterns. It has included the subsection of biomechanics within the Department of Orthopedics, which has allowed greater understanding of the mechanical forces acting on bodies during crashes. It has also included the School of Public Health with its Department of Epidemiology, whose expertise has assisted with analysis of CIREN data and with understanding risk factors for injury. All of this expertise has led to the ability to study injuries on a large scale through the accumulated CIREN data and to make reasonable inferences regarding causes of injury and ensuing prevention strategies.

Seattle CIREN Team: People

The Seattle team includes the following individuals:

Charles Mock, MD, PhD, is one of the few trauma surgeons who also specializes in epidemiology. He holds faculty appointments in both the School of Medicine (Department of Surgery) and the School of Public Health (Department of Epidemiology). He has been with the CIREN team since 1996 and is currently the Principal Investigator.

David Grossman, MD, MPH, is a Professor of Pediatrics. He was the original leader of the Seattle CIREN team and served as P.I. from 1996 through 2000. He is currently the Director of the HIPRC. He is well known for his work in many aspects of injury prevention and, in particular, childhood safety. He is a leader in the field of pediatrics, including such activities as currently serving as Chair of the Committee on Native American Child Health of the American Academy of Pediatrics.

Frederick Rivara, MD, MPH, is the George Adkins Professor of Pediatrics at the University of Washington and one of the original founders of the HIPRC. He is internationally renowned as one of the leaders of injury prevention. He has been instrumental in the Seattle CIREN team's effort to scientifically analyze data and to draw appropriate conclusions on safety implications.

Robert Kaufman, BS, is the crash reconstructionist and data coordinator on the Seattle CIREN team. He has been with the project since its origin in 1996. Prior to that, he worked as a crash recontructionist with the National Automotive Sampling System (NASS) for ten years. He is highly regarded as one of the most experienced crash reconstructionists in the United States.

Kathleen Loeffler, RN, served as a trauma nurse at Harborview Medical Center for over 20 years. She joined the CIREN team in 1998 as the study nurse. She interviews potential study subjects to determine their suitability for the study. For those that qualify, she interviews them in-depth and records the pertinent information about their injuries. She also follows up with phone calls regarding the patient's long-term functional outcome and how the injury has affected their lives in terms of their health, family relations, lost income, and overall well-being.

Allan Tencer, PhD, is a bioengineer. Prior to joining the Seattle CIREN team in 1996, he was already well known for his laboratory research on crash biomechanics including analysis of how crash victims' spines are injured. Dr. Tencer has been instrumental in assisting our CIREN team to understand the biomechanical forces causing injury and to draw suggestions on how such forces may be ameliorated.

Brad Henley, MD, MBA, is a Professor of Orthopedic Surgery at Harborview Medical Center. He recently served as President of the Orthopedic Trauma Association (OTA). His orthopedic expertise has been helpful in understanding the mechanisms of injury leading to broken bones.

Figure A
Seattle CIREN Team

Left to Right: Allan Tencer, Frederick Rivara, Kathy Loeffler, Ken Linnau, Charles Mock, Robert Kaufman. Not pictured are David Grossman, Brad Henley, and Chris Mack.

Fred Linnau, MD, is a radiologist at Harborview Medical Center. He works with the Seattle CIREN team to document the injuries in the form of x-rays, MRI, CAT scans, and other radiological imaging. These images all become a vital component of the CIREN database.

Christopher Mack, MS, is a computer programmer. His expertise has been helpful in Seattle teams efforts to analyze CIREN and NASS data.

Figure A shows the members of the Seattle CIREN team.

Seattle CIREN Team: Activities

The Seattle CIREN team believes that our work has the potential to assist with the development of a safer America and to help to lower the rates of death and disability from automotive crashes through three main mechanisms:

- Surveillance and vehicle design feedback;
- Basic research;
- Outreach activities.

Each of these will be considered in turn.

Surveillance and Vehicle Design Feedback

A basic mission of the entire CIREN project has been to gather information on how automotive safety improvements and related standards have been performing in the real world. It was the view of Dr. Ricardo Martinez, NHTSA Administrator at the time the CIREN network was started, that crash tests employing anthropomorphic test devices (ATDs or more commonly known as "crash test dummies"), although very useful, had significant shortcomings in being able to provide all the information necessary for automotive safety design. Hence the CIREN network was created to provide additional information. It is designed to analyze real-world crashes and to provide feedback for possible design and related motor vehicle safety standards modifications. It may also function as a surveillance system to help detect or provide additional information about unexpected field issues, such as the recently publicized problems with airbag-related injuries to children.

The Seattle CIREN team has been contributing cases to the overall CIREN database for these purposes. A few brief examples will be considered. Airbags have been required in front passenger positions for protection in frontal crashes. Some late model vehicles have begun installing side airbags to improve protection in side impacts. The potential effectiveness of these side airbags has yet to be documented in real world crashes. The Seattle CIREN team has investigated several crashes in which such side airbags deployed (Figure B). Valuable information on the performance of this new safety technology has been included in the CIREN database, for review by NHTSA and the automobile manufacturers.

Figure B
Side Airbag Which Deployed in a Crash

CIREN investigations allow analysis of the effectiveness of such new safety technology.

Federal Motor Vehicle Safety Standard (FMVSS) 214 was promulgated to provide increased protection for occupants in side impact crashes. Through the analysis of side impact collisions, we have been able to analyze FMVSS 214 effectiveness, to a certain extent. FMVSS 214 requires structural support in side doors. This has worked, to some extent, to decrease the severity of injury in side impact collisions. As an example of this, Figure C1 shows the results of a side impact collision in a car prior to FMVSS 214. The door crumpled with significant intrusion, resulting in significant injuries to the chest, abdomen, and pelvis of the driver in this vehicle. Figure C2 shows the results of FMVSS 214. This vehicle was struck at a similar rate of speed to that shown in Figure C1. However, due to the increased side impact protection, there was a limited amount of intrusion and only minor injuries to the occupant.

FMVSS 214 was originally designed to deal with the situation of a passenger car striking another passenger car. This

Figure C1
Side of a Pre-FMVSS 214 Passenger Vehicle after Collision with Another Passenger Vehicle

There was significant intrusion and severe injuries to the occupant.

Figure C2
Side of a Post-FMVSS 214 Passenger Vehicle after Collision with Another Passenger Vehicle

There was minimal intrusion and minimal injuries to the occupant.

Figure C3
Side of a Post-FMVSS 214 Passenger Vehicle after Collision with a SUV (Sport Utility Vehicle)

There was significant intrusion and severe injuries to the occupant. The impact protection mandated by FMVSS 214 had been over-ridden by the higher bumper height and greater mass of the SUV.

was suitable in the past as the majority of America's vehicle fleet were passenger cars. However, over the past decade the vehicle fleet has changed significantly with an increase in the proportion of larger vehicles including sport utility vehicles (SUVs), pick-ups, and other light trucks. Unfortunately, this change in the vehicle fleet has resulted in a lessening of the effectiveness of FMVSS 214. This may be because certain differences between passenger cars and these other vehicles, such as higher bumper height and greater mass of the larger vehicles had not been considered in the currently mandated side impact protection.

This is demonstrated in Figure C3 which shows a passenger vehicle struck on its side by an SUV at a moderate rate of speed, similar to the speeds demonstrated in Figures C1 and C2. The high-riding SUV bumper struck above the reinforcing beams placed to meet FMVSS 214 standards. This caused a significant amount of intrusion higher on the door. The passenger of this vehicle sustained significant injuries to the head, chest, and abdomen, that probably would not have occurred if another passenger vehicle had struck the door instead. Such information is becoming part of the CIREN database and, as such, is available for review by NHTSA and industry personnel and may be considered for possible action to improve the existing side impact protection.

Basic Research

In addition to the individual case reports which our CIREN center provides for the surveillance and vehicle design feedback noted above, we have been undertaking research on larger numbers of crashes and drawing inferences that may be useful in the overall approach to vehicle safety. Several projects are underway. We report here three which have reached publication.

"Effectiveness of automatic shoulder belt systems in motor vehicle crashes." Frederick Rivara, Thomas Koepsell, David Grossman, Charles Mock. *Journal of the American Medical Association*, Vol 283, pg. 2826-2828, June, 2000.

The automatic shoulder harness was originally envisioned as a means by which occupants would have automatic shoulder restraints without having to remember to take the action of buckling up. However, the successfulness of the safety technology was lessened by the fact that many people regarded the shoulder harness as sufficient protection and did not take the action of buckling up their manual lap belt. Reports on the effectiveness of the shoulder harness alone had been mixed in prior research. The effectiveness of the shoulder harness alone is of significance in that approximately 10 million cars with automatic shoulder belt systems are currently in use in the United States. Anecdotal report from our own CIREN database suggested that shoulder harnesses alone were in fact of low effectiveness at preventing injuries. We set out to determine this more scientifically by analyzing over 25,000 crashes in the 1993-1996 National Highway Traffic Safety Administration Crashworthiness Data System (CDS).

We looked at the main outcome measures of death and serious injury and compared them for occupants in frontal crashes using the varying forms of restraints: lap and shoulder belts together, automatic shoulder belt without lap belt, and no restraint use.

This research showed that automatic shoulder belts with lap belts lowered the risk of death by 86% compared to use of no restraint alone. Use of automatic shoulder belts without the lap belts, however, resulted in a lesser (34%) decrease in mortality. Moreover, use of the automatic shoulder belt alone without lap belts was associated with a two fold increase in the risk of serious chest or abdominal injuries.

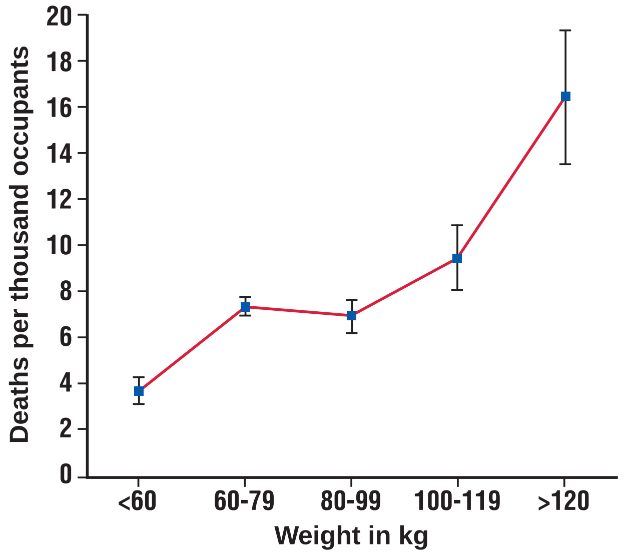
The study concluded with a call for increased awareness of this problem and for increased efforts to alert the public to the need to use lap belts along with automatic shoulder harnesses.

"Effect of body weight on likelihood of death and serious injury in a motor vehicle crash." Charles Mock, David Grossman, Frederick Rivara, Robert Kaufman, Christopher Mack. *Accident Analysis and Prevention*, in press.

Anecdotal reports from our CIREN database suggested that heavier occupants were at an increased risk of injury and death in motor vehicle crashes. There had been smaller studies in the literature suggesting that this may indeed be the case. However, these studies looked at the effect of weight on a variety of different types of mechanisms of injury but not specifically focusing on automobile crashes.

We set out to evaluate the question on a larger scale and more specifically for automobile occupants. We evaluated data on 27,263 occupants in crashes from the 1993-1996 National Highway Traffic Safety Administration Crash Worthiness Data System. We compared the likelihood death and serious injury by different categories of weight. We showed an increased risk of death with increased body weight, as is demonstrated in Figure D. This increased risk of death may, in part, be due to increased medical problems among those who are more over-weight. However, the study also showed an increased likelihood of sustaining severe injuries with increasing weight. These findings persisted even after adjusting for differences in vehicle curb weight, seating position, restraint use, occupant age and gender. The implication of these findings is that vehicle manufacturers may wish to take into consideration heavier occupants' weights in vehicle safety design.

Figure D
Mortality by Occupant Weight



Effect of body weight on likelihood of death in a motor vehicle crash. Occupants indicate those individuals who were riding in vehicles that crashed, in crashes analyzed by the National Automotive Sampling System. Increased risk of death with higher body weight is evident. (Weight categories in lbs: < 60 kg = < 132 lbs; 60 – 79 kg = 132 – 174 lbs; 80 – 99 kg = 175 – 219 lbs; 100 – 119 kg = 220 – 263 lbs; > 120 kg = > 264 lbs). (Bars indicate 95% confidence intervals).

Figure E
Xray of Fractured Femur

This fracture was caused by axial loading from contact with the knee bolster system (Figure F). The forces needed to cause such fractures were estimated in the study described in the text.

"Femur Fractures in Relatively Low Speed Frontal Crashes: The possible role of muscle forces." By A Tencer, R Kaufman, K Ryan, D Grossman, B Henley, F Mann, C Mock, F Rivara, S Wang, J Augenstein, D Hoyt, B Eastman. *Accident Analysis and Prevention*, In press.

The setting of motor vehicle safety standards and the determination of safety ratings of vehicles (e.g. The New Car Assessment Program) have depended on background information on injury thresholds. These thresholds represent the probable force that can be tolerated by the human body and above which injury typically occurs. For example, in frontal crashes, it has been generally accepted, based on cadaver research, that the human thigh can tolerate, on average, 8900 Newtons (2000 lbs) in compression along its axis before a femur fracture occurs. The validity of this estimate has not been well substantiated in actual crashes.

We set out to determine the actual forces required to fracture a femur from the data collected from CIREN crashes. We studied a group of relatively low speed frontal collisions (mean collision speed change of 40.7 kph or 25.4 mph) in which the only major injury suffered by the partly or fully restrained occupant was a femur fracture. However measurements from tests using crash dummies in similar vehicles at greater speed changes (mean of 56.3kph or 35.2 mph) showed that in almost all cases, the femur should not have fractured because the measured loads were below fracture threshold.

In order to explain the fractures that we observed, the loads in the femurs of the occupants in our crash sample were estimated and compared to recognized femur fracture thresholds (derived from previous cadaver research). Femur loads in the crashes we studied were estimated by inspecting the scene and measuring crush deformations in each vehicle, defining occupant points of contact and interior surface intrusion, and calculating crash change in velocity (delta V) and deceleration. Measured femoral loads in crash dummies from test data in comparable vehicles were scaled to the crashes in our sample by adjusting for differences in crash deceleration, occupant weight, and restraint use.

All the 20 occupants in our sample sustained at least a transverse midshaft fracture of the femur with comminution (multiple fragments), which is characteristic of axial compressive impact, causing bending and impaction of the femur (Figure E). However, the average estimated femur compressive load was 8187N (1,840 lbs), which is below

Figure F
Knee Bolster System with Occupant Contacts Outlined in Red Tape

the generally accepted threshold of 8900N (2000 lbs). Moreover, based on the previous cadaver tests, the average probability for fracture in our study was only 19%. In fact, in 13 crashes the fracture probability was less than 10%.

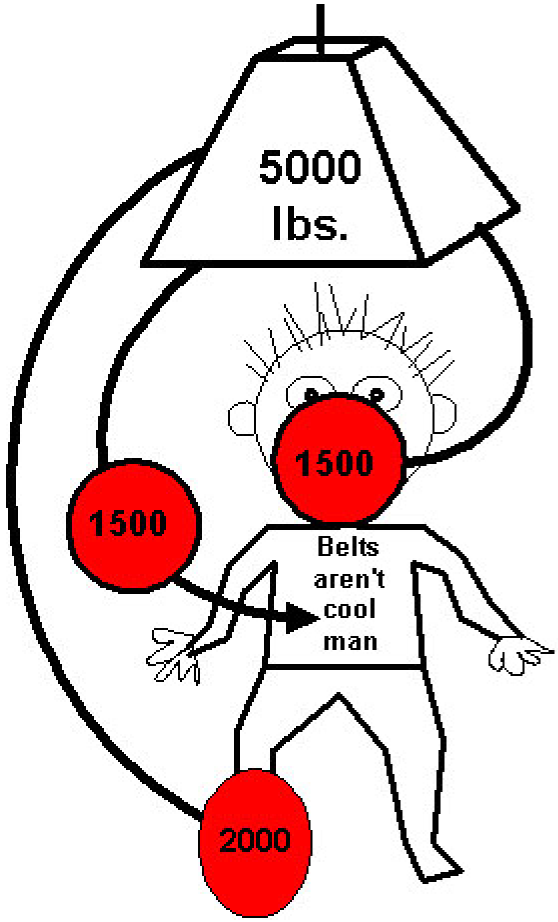
Two factors we propose might explain the discrepancy. The occupant's femur was out of position (typically the driver's right foot was on the brake) and did not impact the knee bolster, instead hitting stiffer regions around or on the steering column. The knee bolster (Figure F) is the region of the dashboard designed to absorb knee impact when the occupant is sitting, as would a crash dummy, with both legs forward and both feet on the floor, not with the right leg angled and the foot on the brake. Additional compressive force on the occupant's femur probably resulted from muscle contraction due to bracing for impact. Adding the estimated internal load on the femur from muscle contraction to the estimated external load from knee to dashboard impact, increased the femur loads beyond threshold, explaining the fracture in all but one case.

Since crash tests using dummies do not simulate out of position knee to dashboard contact or muscle contraction loading, they may underestimate the total loads acting on the femur during actual impacts where the driver is avoiding and bracing for the crash. These results may have implications for altering knee bolster design to accommodate out of position knee to dashboard contact and the internal compressive loads caused by muscle forces from bracing.

Outreach Activities

The Seattle CIREN team has been engaged in outreach activities with a variety of groups including physicians, nurses, paramedics, law enforcement personnel, and members of the lay public including high school students. An educational intervention known as "The Force is With

Figure G
Audiovisual Aid from "The Force is With You," Project



This program utilizes basic principles of physics to demonstrate the forces acting on the human body during crashes. This information has been useful to help students see the importance of wearing seatbelts, with the ultimate goal of increasing their belt usage.

You" has been developed with the idea of applying lessons from physics to demonstrate to high school students the importance of seatbelt use (Figure G). The basic idea is to show the forces acting on the human body in a crash and especially to emphasize how severe these are, above and beyond what the public usually imagines. This project has involved an interaction of existing activities from the HIPRC and information obtained from the CIREN project. This teaching module has been put on in five high schools around the Seattle metropolitan area, reaching nearly 1000 students. It has been exceptionally well received with many requests from other schools for this to be put on.

In addition to the above noted program, CIREN staff (principally Rob Kaufman) have put on over 60 outreach presentations (Figure H). For physicians and nurses, this has involved discussions of the scientific basis of the CIREN project and how this information is useful to prevent and

Figure H
Mr. Robert Kaufman Delivering an Outreach Presentation on Crash Reconstruction at a Law Enforcement Technical Training Session

treat injuries. For paramedics, the emphasis has been training for recognition of exceptionally dangerous crash patterns which should increase the level of suspicion for occult injuries. For traffic police, the emphasis has been improvement in their skills in crash reconstruction with special emphasis on injury-related aspects of the analysis.

The various forms of outreach have been very popular with the target groups with more requests for subsequent sessions than we are able to handle with our staff and budget at this time. We are currently working on the design of pre-formatted teaching modes such as videos and CD-ROMs to increase the reach of these training activities.

In addition to formal presentations, the training from the CIREN project has been applied on an on-going basis. All of the Advanced Life Support (ALS) ambulance rigs in

Figure I
Doctors and Nurses in the Emergency Department of the Harborview Medical Center View Digital Photographs of Crashed Vehicle

Such photographs are brought in from the scene by paramedics. The photographs demonstrate particular crash patterns that heighten vigilance for occult injuries.

Seattle and surrounding King County have been supplied with digital cameras to take pictures of the exterior and interior of damaged vehicles in the most severe crash situations. The photographs are brought into the emergency room on floppy disk. These are then viewed by doctors and nurses caring for the injured person (Figure I). Especially dangerous crash deformation patterns, such as those with high degrees of intrusion, result in increased evaluation and monitoring for occult injuries.

In conclusion, the Seattle team feels that the CIREN project has significantly contributed to our pre-existing injury prevention efforts and hence to a safer America. Through a combination of feedback on the performance of safety technology; through basic research into automotive safety; and through outreach and training, we believe we have contributed to a better understanding of automotive safety and injury causation."

APPENDIX: List of Seattle CIREN Outreach Activities:

Part 1: Overview Listing for 1999–2001

January 1999, Oregon State DOT Three Flags Safety Conference

April 1999, National Trauma Care 99, Harborview Medical Center

May 1999, "Coffee Talks," Harborview Medical Center monthly staff meeting

June 1999, NHTSA LifeSavers National Conference

July 1999, Washington State Traffic Safety Commission / Three Flags Conference

August 1999, Harborview Medical Center Board Meeting

September 1999, 3rd Annual CIREN Conference, San Diego

October 1999, Annual Oregon Transportation Safety Conference

October & November 1999, Harborview Injury Prevention and Research Annual Training.

November 1999, Ford Motor Engineers, Video conference

November 1999, Stanford University, Stanford Medical Trauma Conference

December 1999, Harborview Medical Center Surgery Department Seminar.

January 2000, King County Medical Examiners Traffic Conference.

February 2000, Trauma Care for the New Millennium, Spokane WA

February 2000, Idaho Office of Highway Safety, Safety Seatbelt Summit.

March 2000, King County Traffic Coalition Seminar

March 2000, District 7 of the Washington State Patrol Reconstructionist training.

April 2000, Harborview Medical Center staff monthly "Brown Bag staff meeting"

May 2000, NHTSA Region X, All hands Meeting

May 2000, High School Outreach Project Pilot, "The Force is with you"

May 2000, Alaska Highway Safety "Buckle up" Seatbelt Summit, Anchorage, AK

April 2000, HIPRC research seminar on Femur fractures CIREN study

May 2000, HIPRC research seminar on Air bag technologies with live deployment in parking lot

June 2000, Washington State Law Enforcement Crash Investigator Training, Criminal Training Center.

July 2000, Idaho Buckle up Seatbelt summit

July 2000, CIREN public presentation, "Side impacts- Affects of Door panel geometry and stiffness"

August 2000, Annual Washington State EMS and Trauma Conferences

September 2000, Seattle Medic Tuesday Series Meeting

October 2000, Oregon Department of Transportation- Annual Traffic Safety Conference

September 2000, NAME National Association of Medical Examiners conference

November 2000, Pediatric Grand Rounds at Children's Hospital

December 2000, The Force is With You – High School Outreach

December 6, 2000, Washington State Driver Impaired conference, Washington Traffic Safety conference

January 2, 2001, Harborview Medical Center Paramedic Training

January 10, 2001, Oregon DOT, Three flags Law Enforcement conference

January18, 2001, Bellevue EMS medic meeting

Feb 1st , 2001, Kitsap County EMS monthly training meeting.

Feb 8th, 2001, Child Safety Technician Regional Update Training, Portland Oregon

March 16th, 2001, CIREN NHTSA Public quarterly meeting

March 17th, 2001, Wenatchee EMS North Central Washington EMS conference.

April 10th , 2001, National Harborview Medical Center Trauma Conference.

April 10th , 2001, National Harborview Medical Center Trauma Conference Workshops

April 13, 2001, Harborview Medical Center Thoracic Trauma and Critical Care Conference

April 27th. 2001, Legacy Emmanuel Trauma Center, Portland Oregon

April 28th, 2001, Mount Vernon - Northwest Washington State EMS conference

May 18th , 2001, Alaska Buckle Statewide Seatbelt summit

May 29, 2001, Pierce County EMS Training Conference

June 5, 2001, Law Enforcement Crash Investigator Training, Criminal Justice Training Center

June 11, 2001, Trauma Surgeon Meeting

June 20, 2001, CIREN NHTSA Public Meeting, Theme: "Getting the word out – CIREN"

July 11, 2001, City of Eugene Oregon Medic and Fire Rescue Training

July 20, 2001, Washington State Patrol Technician Training

August 15, 2001, Airlift Northwest Flight Nurses training

September 6, 2001, CIREN NHTSA Public Meeting, Theme: SUV's

September 2001, Idaho Buckle up Seatbelt summit

October 22, 2001, Alaska DOT, Transportation and Technology Conference, Anchorage AK

October 26, 2001, Oregon Department of Transportation Traffic Safety Conference

November, 2001, Alaska statewide EMS Symposium training

San Diego County Trauma System

CIREN Center

CIREN Program Report

San Diego County Administration Center

Children's Hospital & Health Center

Scripps Mercy Hospital

Palomar Medical Center

Scripps Memorial – La Jolla

Sharp Memorial Hospital

UCSD Medical Center

CIREN Center: Program Structure

The San Diego CIREN Center is a collaborative effort between the six regional Trauma Centers and the County of San Diego, Health & Human Services Agency, Division of Emergency Medical Services. The unique configuration of the San Diego CIREN program, incorporating six hospitals rather than one, presents logistical challenges for its participants but also offers research outcomes rich in rewards.

The CIREN Program was established in 1996 through the General Motors Corporation settlement agreement and is currently underwritten through a Cooperative Agreement with the NHTSA. The Principal Investigators for the project are:

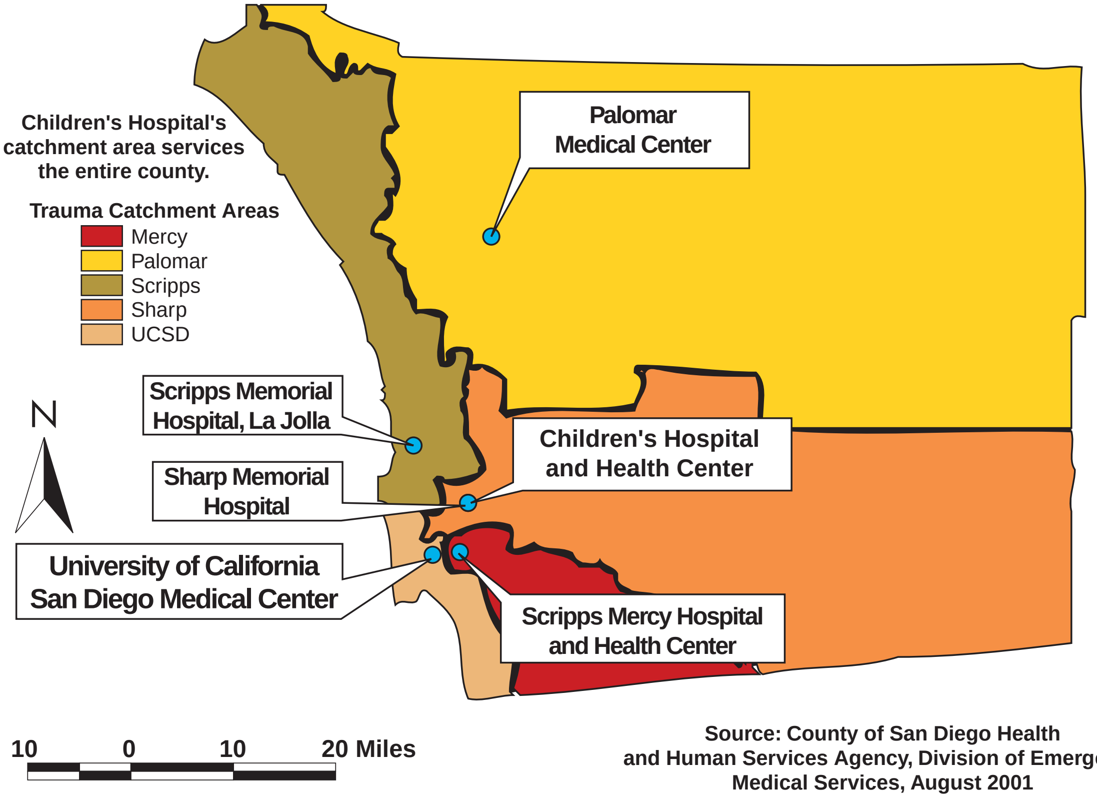
- **Gail F. Cooper, Administrator**, County of San Diego Office of Public Health
- **A. Brent Eastman, MD, Director,** Trauma Services at Scripps Memorial Hospital – La Jolla
- **David B. Hoyt, MD, Director**, Trauma Services at the University of California San Diego (UCSD) Medical Center

The Principal Investigators are supported by the Trauma Medical Directors and nurse administrators, researchers and case managers at the county's trauma centers. The participating Trauma Centers are:

- Children's Hospital and Health Center, San Diego
- Palomar Medical Center
- Scripps Mercy Hospital
- Scripps Memorial Hospital – La Jolla
- Sharp Memorial Hospital
- UCSD Medical Center

The San Diego region is rich in diversity. San Diego County, the fifth largest county in the United States, is home to 2.8 million residents and approximately 1.8 million licensed drivers. Covering 2.7 million acres, San Diego County has over 7,700 miles of roadways, 600 miles of which is made up of state highways. San Diego County is bordered by the Pacific Ocean to the west, Camp Pendleton to the north, the Anza-Borrego desert to the east, and the U.S.-Mexico border to the south. These

Trauma Catchment Areas
County of San Diego



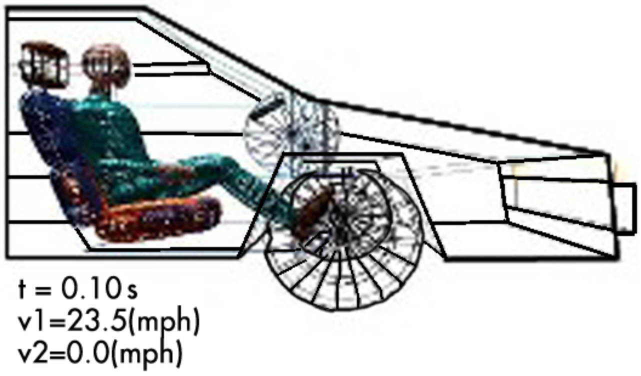
Source: County of San Diego Health and Human Services Agency, Division of Emergency Medical Services, August 2001

boundaries insulate San Diego from adjacent regions, and in a sense, the County can be considered a natural laboratory for research.

The San Diego CIREN Center draws project occupants from rural, suburban and urban regions. The crash scenarios, like the County's population, are varied and offer an array of research opportunities for the CIREN program. As evidenced from the following statistics, motor vehicle crashes continue to be a concern for the residents of San Diego. From July 1998 through June 1999, there were a total of 14,941 motor vehicle crashes in San Diego County, injuring 19,828 victims. Motor vehicle occupant (MVO) crashes were most common (82%), followed by pedestrians (7%), pedal cycle (5%), and motorcycles (4%). Almost 11 percent (10.9%) of victims were injured in Driving Under the Influence (DUI) crashes. Crashes involving unsafe speed made up 30.5% of the cases and sign/signal violations were associated with 9.8% of the crashes. Twenty percent of children under age 15 injured in DUI crashes were passengers of the DUI driver. Statistics indicate that nearly six percent (5.6%) of victims injured in MVO crashes were unrestrained (10.2% unknown restraint use). Child restraints were not used in less than 2%, however misuse rate is estimated at 96.4%. Of victims injured, 0.9% were killed, 3.3% suffered severe injury, 25.6% had other visible injuries, and 70.2% had a complaint of pain. These statistics reflect the scope of the safety problem that motor vehicle crashes present in San Diego. The research efforts of the CIREN program have the potential to help mitigate the death, disability, and human suffering associated with

Steve Erwin, CIREN San Diego Crash Investigator, During Case Review

Animated Simulation of Frontal Offset Crash



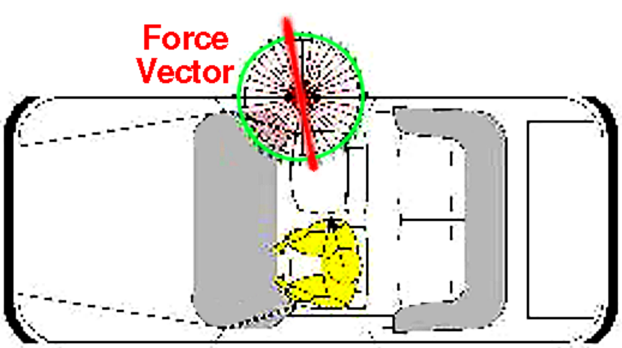
these crashes and to have repercussions nationally, as well as locally.

Trauma System Participation

The San Diego CIREN program benefits from the seventeen-year working relationship of the San Diego Trauma System. The trauma system partners include the six Trauma Centers, the Division of Emergency Medical Services (EMS) and the Office of the Medical Examiner. Established in 1984, San Diego's trauma system is nationally recognized for its pioneering efforts, not only in patient care, but for its integration between EMS and Public Health and its strides in quality improvement activities. The trauma system participants have engaged in collaborative efforts to improve the triage, transport and treatment of injured patients, including motor vehicle crash occupants.

Since its inception, the trauma system has focused on the multidisciplinary system of care through an inclusive Medical Audit Committee (MAC) process which includes trauma physicians and nurses, other surgical specialties, the Medical Examiner, and prehospital and Emergency Department personnel. The MAC reviews trauma cases for prehospital and hospital delivery of care as a means to improve patient outcomes and ensure the provision of quality medical service.

Principal Direction of Force for Far Side Crash



San Diego draws from the strength of the MAC multidisciplinary concept to provide a basis for the CIREN injury and crash analysis process. The MAC multidisciplinary approach has been enriched by the addition of crash reconstructionists, highway safety engineers, and prehospital providers. Collectively, the core participants have decades of experience in injury identification, injury causation, and crash dynamics. The CIREN process has fortified their understanding of occupant kinematics, vehicle design and biomechanics. As the case review system has matured the CIREN team has incorporated the use of crash video clips, simulations, and occupant motion vectors to assist with injury sourcing in challenging cases. Case analysis has provoked discussion regarding vehicle crashworthiness, injury patterns, and injury prevention opportunities.

The People

Ms. Gail F. Cooper, has been instrumental in establishing Emergency Medical Service Systems, Trauma Systems, Injury Control programs, and Public Health policy at the local, state and national level for over 25 years. She has assisted state and local communities in further development and refinement of their respective EMS systems, strengthened data collection and evaluation components of EMS and Trauma systems, and formulated policies allowing for the integration of EMS, Trauma, and Injury programs.

A. Brent Eastman, MD, **FACS** is the N. Paul Whittier Chair of Trauma and Medical Director of Trauma Services at Scripps Memorial Hospital, La Jolla. Dr. Eastman served as Chairman of the Committee on Trauma for the American College of Surgeons from 1990 to 1994 and he has been a Co-Chair of the San Diego Trauma System Medical Audit Committee since its inception. The knowledge gained from these responsibilities, as well as his extensive clinical experience, ensure the CIREN program gets the benefit of Dr. Eastman's trauma background. Dr. Eastman has authored or co-authored more than 30 publications related to trauma care and trauma systems.

Dr. David B. Hoyt, MD, FACS is the Vice Chairman of the Surgical Department and Chief of the Division of Trauma, Burn, Surgical Critical Care. In 1996 he was awarded The Monroe E. Trout Professorship in Surgery at UCSD. He currently serves as Chairman of the UCSD Medical Group Board of Governors. Dr. Hoyt has distinguished himself in Traumatology having delivered numerous named lectures, received significant awards from his colleagues and scientific organizations while serving in positions of leadership. In addition to an active clinical schedule, he has been intensely involved in both graduate and undergraduate teaching at UCSD. He is currently the President-elect of the American Association for the Surgery of Trauma, President of the Society of General Surgeons, Secretary of the Shock Society, and the Chairman of the American College of Surgeons Committee on Trauma. Dr. Hoyt has dedicated considerable time to research activities and is the author of over 300 publications.

Ms. Sharon E. Pacyna, RN, BSN, MPH has been the Project Manager for the San Diego CIREN Program since 1997. She has been active in nursing for almost 30 years, and has extensive experience in both the clinical and administrative aspects of trauma patient care. Her background has cultivated Ms. Pacyna's knowledge of injury mechanisms and injury diagnosis and treatment. She is responsible for coordinating CIREN activities on a day-to-day basis and overall program oversight. Additionally, Ms. Pacyna has delivered presentations locally and nationally, participated in the alpha testing of the CIREN database, and collaborated with other CIREN members to develop quality assurance processes and outreach programs.

Mr. Steven M. Erwin joined the San Diego CIREN Team in July 2000. He has over sixteen years of experience in Federal Department of Transportation motor vehicle related crash research, including six and a half years in quality assurance at the National Automotive Sampling System (NASS) Zone Center level, and ten years of NASS field data collection. This background provides Mr. Erwin with extensive knowledge, both historical and applicable, of NASS protocol and ground floor understanding and operation of the Electronic Data Collection System (EDCS).

As a CIREN Crash Investigator, he conducts all field data collection, crash dynamics reconstruction and synthesis of the data into the EDCS. He assists in the linking of injury to the mechanism injury and the propagation of technical and educational information through presentations to medical and industry audience. He formulates vehicle dynamics, occupant kinematics and injury analysis into detailed written reports.

Ms. Teresa M. Vaughan, RN, BSN, CCRN is the Assistant Project Manager for the San Diego CIREN program. Her extensive clinical experience with trauma patients has provided her with knowledge of crash injury patterns and mechanism of injury. Throughout her employment she has been responsible for AIS coding, data collection and entry into trauma registry databases. Her responsibilities for CIREN include conducting patient interviews, obtaining digital images of patient injuries, review of all NASS AIS coding, and CIREN database entry. Ms. Vaughan is an active participant in development of presentations for quarterly CIREN meetings in Washington DC, as well as monthly case reviews among the six trauma centers.

Mary D. Kracun, RN, PhD, CCRN is the Investigational Clinician for the Trauma Service at Scripps Memorial Hospital, La Jolla, California. Dr. Kracun has been involved in Critical Care, Emergency and Trauma Nursing for more than 25 years. She has been active with the American Association of Critical-Care Nurses, serving on both local and national Boards of Directors. Dr. Kracun has participated in the development of the CIREN computer database data elements and quality assurance activities related to the CIREN program. Additionally, she has played an active role in the development of presentations for the CIREN Quarterly Meetings as well as delivering CIREN educational programs at both local and regional conferences.

CIREN San Diego is fortunate to have the input from the Medical Directors and Nurse Managers from the six Trauma Centers. They identify potential candidates for the CIREN study and provide in-depth injury documentation and injury description, which are invaluable during the case analysis. These partners include:

Children's Hospital, San Diego

Barry E. LoSasso, MD, FACS, FAAP
Trauma Medical Director

Susan A. Cox, RN, MS, CEN
Trauma Services Director

Renee Douglas, RN
Assistant Trauma Coordinator

Scripps Memorial Hospital, La Jolla

A. Brent Eastman, MD, FACS

N. Paul Whittier, Chair of Trauma

Mary D. Kracun, RN, PhD, CCRN
Investigational Clinician, Trauma

Jackie Martinez, RN, BSN, CCRN
Trauma Case Manager

Jennifer Wilson, RN, BSN, ONC
Trauma Case Manager

Cheryl Wooten, RN, MSN, CNRN
Trauma Program Manager

Palomar Medical Center

Thomas Velky, MD
Medical Director Trauma Service

Patricia Renaldo, RN, BSN
Trauma Clinician

Shannon Durbin-Yates, RN, BSN
Trauma Clinician

UCSD Medical Center

David B. Hoyt, MD, FACS
Director, Trauma Services

Linda Richards, RN, MN
Study Coordinator

Beth Romeril, RN, MSC(A)
Research Nurse

Scripps Mercy Hospital

Michael J. Sise, MD, FACS
Medical Director, Trauma Services

Dorothy M. Kelley, RN, MSN, CEN
Trauma Program Manager

Sharp Memorial Hospital

Frank R. Kennedy, MD, FACS
Director, Trauma Services

Kathi Ayers, RN, MSN, CCRN, CFNP
Trauma Program Manager

Linnea Trageser, RN, MS, ANP
Trauma Nurse Practioner/CNS

The Role of Emergency Medical Services

Personnel from the County of San Diego, Emergency Medical Services provide administrative and managerial oversight to the CIREN project. In addition to their participation in the Trauma System, EMS has on-line access to all prehospital provider data. Housed in the office of EMS is a wide area network computer system, linking prehospital providers with Emergency Departments in a real time prehospital patient information system identified as the QA Net. The QA Net serves many purposes. It is a database for all prehospital patient information in which an EMT-P makes patient contact. It also provides current information on the resource status of all Emergency Departments and Trauma Centers. If a Trauma Center's on-call and back-up surgeons are all busy in the Operating Room due to multiple admissions, this information is entered into the QA Net so that triage/destination decisions can be based on resource availability.

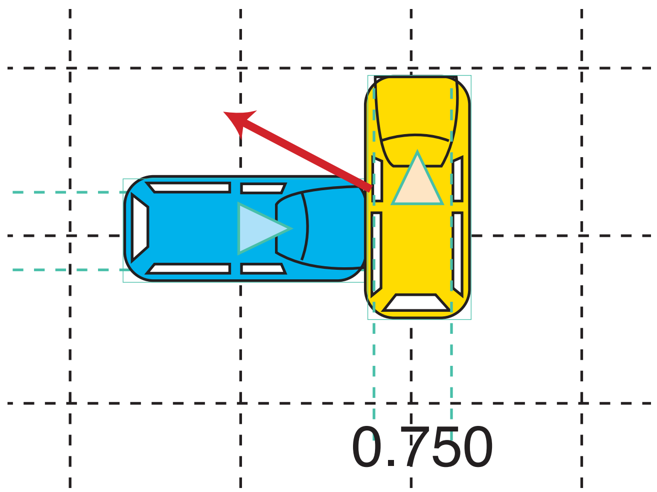
CIREN utilizes the QA Net to assist in identifying potential crash study candidates. On a daily basis the QA Net is queried for all injury patients transported to the six Trauma Centers. EMS staff review these computerized prehospital records, deleting all but the motor vehicle crash victims. The information remaining in this dedicated CIREN database is printed and faxed to the Trauma Centers to serve as

Example of San Diego County QA Net Hospital Status
Emergency Receiving Status

HOSPITAL NAME-CODE		TRAUMA	HOSPITAL	CT	ICU	OTHER	OTHER
ALVARADO	1		OPEN	OPEN	OPEN	OPEN	OPEN
CHILDRENS	56	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN
CORONADO	49		OPEN	OPEN	OPEN	L/D FULL	OPEN
FALLBROOK	38		OPEN	OPEN	OPEN	OPEN	OPEN
GROSSMONT	12		OPEN	OPEN	OPEN	OPEN	OPEN
KAISER	16		OPEN	OPEN	OPEN	NO TELE	OPEN
MERCY	19	BYPASS	OPEN	DOWN	OPEN	OR FULL	OPEN
PALOMAR	22		OPEN	OPEN	OPEN	OPEN	OPEN
PARADISE VALLEY	24		OPEN	OPEN	OPEN	OPEN	OPEN
POMERADO	59		OPEN	OPEN	OPEN	OPEN	OPEN
SCRIPPS CV	2		ED SAT	OPEN	OPEN	OPEN	OPEN
SCRIPPS ENCINITAS	45		OPEN	OPEN	OPEN	OPEN	OPEN
SCRIPPS LJ	30	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN
SHARP	31	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN
SHARP CV	46		ED SAT	OPEN	OPEN	OPEN	OPEN
THORNTON	23		OPEN	OPEN	OPEN	OPEN	OPEN
TRI-CITY	32		OPEN	OPEN	FULL	OPEN	OPEN
UCSD	35	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN
VILLA VIEW	54		OPEN	OPEN	OPEN	OPEN	OPEN

a guide for identifying program candidates. Available data corresponds with many of the CIREN inclusion criteria such as occupant position, type of crash (frontal, side), seat belt use, child restraint system use, airbag deployment, extrication information, and names of the on-scene prehospital providers.

Primary Occupant Motion Vector



Simulation of side impact crash indicating primary vector of occupant

In calendar year 2000, CIREN screened 6,037 motor vehicle crash occupants transported to San Diego Trauma Centers. Forty-eight patients were enrolled in CIREN. At least one exclusion reason was documented for the remaining 5,989 patients. The most frequently cited exclusion reason was lack of severe injury (79.5%). The explanation for this high percentage is because injury severity, as opposed to year of vehicle for example, is readily available to medical personnel. The next highest exclusion categories were; inappropriate crash configurations - 5.9% (rear collisions, multiple rollovers), lack of active or passive restraints in frontal crashes – 5.5%, and vehicles that did not meet Late Model Year criteria – 3.3%.

The QA Net information not only assists CIREN personnel in identifying inclusion patients but also provides access to scene documentation and eyewitness accounts from scene personnel, which can be key to determining crash analysis.

EMS and the Trauma Centers enjoy a close and productive relationship with personnel from the County of San Diego, Medical Examiner's Office. In addition to providing detailed and descriptive autopsy reports, the Medical Examiner will call the CIREN Project Manager with crash scenarios appropriate for CIREN inclusion. The Medical Examiner also has a background in crash dynamics and provides insight into the biomechanics of injury.

Research and Prevention

From August 1984 through June 1999, more than 93,000 patients were admitted to San Diego County's designated Trauma Centers and the leading cause of injury and death was motor vehicle crashes. In 1998/1999, among traumatic deaths, motor vehicle occupant crashes were the leading cause of death (210) and Years Potential Life Lost (8490.1). Years Potential Life Lost (YPLL) calculates the years of life lost due to a death using the average life expectancy as an estimate for the total length of life. These figures emphasize the need for prevention efforts related to motor vehicle crash injury.

CIREN focuses on research and prevention of injuries and death from motor vehicle crashes. San Diego is in a unique position to meet the mission and goals of CIREN due to the prior research efforts of the San Diego Trauma Centers. In addition to hospital-specific research the Trauma Centers have established the Trauma Research and Education Foundation (TREF), a non-profit organization to facilitate centralized prevention and education efforts. The past dedication to and experience in research, provides benefits to the CIREN program.

San Diego has made advances in the process for reviewing crash dynamics, occupant kinematics and injury causation. Case review participants include crash reconstructionists, highway safety engineers, and medical/nursing personnel knowledgeable in injury identification and injury mechanisms. Each case is analyzed in-depth to determine crashworthiness, human tolerances and environmental factors as related to injury patterns. These reviews have led to several research questions and study options. One area investigated in-depth by San Diego was the biomechanics and crash factors responsible for mediastinal injuries. It discovered that restraint systems, although key in preventing a multitude of serious injuries, could result in blunt rupture of the heart and transection of the aorta. These findings were discussed at the Second Annual CIREN Conference and the audience was encouraged to design, test and develop alternate safety belt design systems to mitigate these injuries (please refer to abstract at the end of the San Diego chapter).

In addition to conducting case reviews independently, San Diego hosted the Michigan CIREN Center and conducted a joint case review session. San Diego also presented at a multi-CIREN Center review in Boston and participates in monthly CIREN Teleconference Case Review.

The County of San Diego provides procedures and protocols for prehospital personnel. This year the triage criteria for the County were revised and based, in part, on information provided by the CIREN Crash Investigator. Education regarding these criteria is being provided for paramedics and Emergency Department physicians and nurses.

San Diego CIREN staff have volunteered for several

CIREN subcommittees and projects including the Quality Assurance subcommittee, alpha testing for the CIREN database, CIREN Outreach subcommittee.

San Diego has promoted efforts to engage in community activities while enhancing its understanding of prehospital care. During a sister CIREN visit, San Diego arranged for the City of Santee Fire Department, a local county paramedic agency, to conduct an extrication demonstration. Maneuvers including dash roll-up, cutting A and B Pillars and use of the jaws-of-life were demonstrated.

Financial Considerations

The following table uses a NHTSA formula to project motor vehicle crash costs for 1998/1999 San Diego CIREN patients. The NHTSA cost figures are based on a report entitled "The Economic Cost of Motor Vehicle Crashes, 1994". Unit costs are sorted by the occupant's highest Abbreviated Injury Score (AIS), which is an indicator of patient injury severity. Please note the NHTSA 1994 figures are national averages and do not reflect the actual costs in San Diego, nor have they been adjusted for 1998/1999 inflation. The NHTSA economic cost components are comprehensive and include productivity losses, property damage, medical costs, rehabilitation costs, travel delay, legal and court costs, emergency service costs, insurance administration costs, premature funeral costs and costs to employers. It is difficult to assign a monetary figure to the physical and emotional pain borne by patients and their families involved in motor vehicle crashes. However, these estimates delineate the devastating financial losses incurred from these injuries.

Estimated Cost of Motor Vehicle Crashes

Severity per AIS	1998/99 CIREN Patients by MAIS	NHTSA Cost Formula per AIS	Estimated Costs for San Diego CIREN Patients
1	11*	$3,777	$41,547
2	8*	$31,164	$249,312
3	52	$98,011	$5,096,572
4	12	$221,494	$2,657,928
5	15	$697,533	$10,462,995
6	3	$822,328	$2,466,984
TOTAL			$20,975,338

* AIS 1 and 2 injuries are primarily pediatric patients

A Case Study

The following is an example of how the CIREN multidisciplinary approach is incorporated into case analysis and how this can have branching impacts locally and nationally. San Diego Trauma Center researchers identified an interesting case in which two occupants in the same vehicle had identical aortic lacerations. Only one of the patients agreed to participate in the CIREN study but there was a discrepancy as to whether our study patient was the driver or the passenger. CIREN staff contacted the prehospital providers to get a first hand account of scene events including occupant positions. The paramedic information also helped the Crash Investigator pinpoint the scene location, which was difficult to determine because the vehicle went airborne from an Interstate cloverleaf and landed approximately 165 feet below. During the CIREN Case Review, crash dynamics, occupant kinematics, and the biomechanics of the aortic injury were analyzed and consensus was reached regarding the dynamics responsible for the injury. As part of CIREN's educational objectives, patient outcome was shared with the prehospital personnel who were very interested in the case and appreciative of the feedback. Case analysis was also discussed with the other CIREN Centers on a Grand Rounds Teleconference, where a spirited and educational discussion ensued.

Of special consequence in this case is the nature of the injury reviewed. Aortic injuries can be devastating and, depending on the extent of injury, many patients will die at the scene of the crash. Surviving patients are transported to the hospital but a significant percentage die if not diagnosed expediently. Therefore, identification of patients with a high risk for aortic injury presents a tremendous opportunity to save lives. To this end, CIREN Centers are analyzing crash configurations to determine if they can characterize factors that might provide a high index of suspicion for aortic injuries. This case highlights the importance how analysis of real life crashes, by a multidisciplinary team, can assist in the understanding of the mechanism and diagnosis of injuries.

Outreach Efforts

San Diego recognizes the importance of providing education to the first responders and medical community regarding crash dynamics, occupant kinematics, and associated injury patterns to assist with the diagnosis and treatment of motor vehicle-related injuries. CIREN outreach efforts for law enforcement, prehospital providers, emergency department personnel (20 receiving hospitals) and trauma center personnel will enhance patient triage, transport, treatment, and outcome. Below is a list of local and national presentations provided by San Diego CIREN.

Presentation Roster

National Presentations/Posters

Oct. 18–20, 2001 Orthopedic Trauma Association 17th Annual Meeting San Diego – Poster Session

Audience: Over 600 orthopedic surgeons, nurse practitioners, and nurses attended the conference.

Presenters: Sharon E. Pacyna, BSN, MPH, Steven M. Erwin, Crash Investigator, Teresa M. Vaughan, RN, BSN, Mary Kracun, BSN, PhD

Presentation included a Poster Session with an overview of the national CIREN Program and a continuously playing PowerPoint™ presentation which depicted occupant kinematics, vehicle reconstruction, crash video clips and case presentations. Additionally, a crashed vehicle was displayed with contour gage and calibrated rods sticks demonstrating crush and deformation.

June 21, 2001 Emergency Department Personnel – Piecing it Together

Audience: CIREN Quarterly Meeting, Washington D.C. MD's, RN's, Engineers, Automotive Manufacturing Executives and Researchers

Speakers: Sharon E. Pacyna RN, MPH and Steve Erwin, Crash Investigator

San Diego CIREN's presentation developed for Emergency Department personnel includes CIREN overview, basic crash dynamics, and patient inclusion criteria. It emphasized the importance of injury documentation and crash details. Crash dynamics associated with injury patterns was discussed.

Mar. 16, 2001 Real Life Injuries in Offset Frontal Crashes

Audience: CIREN Quarterly Meeting, Washington D.C. MD's, RN's, Engineers, Automotive Manufacturing Executives and Researchers.

Speakers: A. Brent Eastman, MD and Steve Erwin, Crash Investigator

Review of San Diego CIREN incidence of FY offset frontal crashes including patient outcome. Presentation of two offset frontal crashes with vehicle and occupant simulations.

Nov. 30, 2000 Diaphragm Injuries

Audience: CIREN Quarterly Meeting, Washington D.C. MD's, RN's, Engineers, Automotive Manufacturing Executives and Researchers

Speakers: David B. Hoyt, MD and Steve Erwin, Crash Investigator

Incidence of diaphragm injuries in the CIREN database as related to crash type, patient outcome, and associated injuries. Discussion of mechanism of injury.

Jul. 21, 2000 Side Impact – Case Presentation

Audience: CIREN Quarterly Meeting, Washington D.C. MD's, RN's, Engineers, Automotive Manufacturing Executives and Researchers

Speakers: Sharon E. Pacyna, RN, MPH and Steve Erwin, Crash Investigator

The presentation provided an in-depth review of a side impact with air bag deployment. Detailed vehicle/occupant photographs and a MSMAC simulation provided specific case information. CIREN and NASS query information was included for comparison. The format included audience participation.

May 5, 2000 Lower Extremity Injuries

Audience: CIREN Quarterly Meeting, Washington D.C. MD's, RN's, Engineers, Automotive Manufacturing Executives and Researchers

Speaker: A. Brent Eastman, MD

The presentation included lower extremity injury statistics from the San Diego County CIREN Program, two case presentations with injury/biomechanical analysis, and an occupant simulation depicting lower extremity kinematics with and without a seatbelt.

Oct. 28, 1999 Aortic Injuries in Near-Side Collisions

Audience: The Third Annual CIREN Conference. MD's, RN's, Engineers, Automotive Manufacturing Executives and Researchers

Speakers: David B. Hoyt, MD and Jeffrey Augenstein, MD.

Mechanisms of injuries for frontal and side impact collisions was reviewed. The importance of having a high index of suspicion was emphasized to ensure the institution of life saving measures.

Sept. 15, 1998 Mediastinal Injuries

Audience: Second Annual CIREN Conference, Ann Arbor Michigan. MD's, RN's, Engineers, Automotive Manufacturing Executives and Researchers.

Speaker: David B. Hoyt, M.D.

Dr. Hoyt presented historical and current research on mechanisms of aortic and blunt heart injuries. Research of multi-center CIREN cases were analyzed for crash type, association of chest injuries, and of specific injury mechanisms.

May 20, 1998 Correlating Crash Injuries: People and Vehicles

Audience: 18th Annual Conference of the National Association of Orthopedic Nurses, San Francisco California. RN's, PT's, OT's. Attendance ~75; 1,800 registrants at conference.

Speaker: Mary Kracun, RN, PhD, CCRN

Presentation included vehicle safety features, real and potential injures expected in crashes and the importance of knowing specifics of the crash and how this information is beneficial in caring for patients injured in vehicle crashes.

Regional/Local

Oct. 22, 2001 Vehicle Intrusion And Crush As Indicators For Trauma Triage

Sep. 3, 2001	CIREN Update: Side Impact Case Presentations
Jun. 15, 2001	The Case of the Human Crash Dummies
Mar. 6, 2001	What Really Happens to You When You're in a Crash!
Feb. 13, 2001	Vehicle Intrusion and Crush as Indicators for Trauma Triage
Aug. 11, 2000	Safety Facts You Should Know
Jul. 13, 2000	CIREN Update: Lower Extremity Injuries
June 2000	Trauma Research: Making it Real
Jan. 15, 2000	The CIREN Project – New Dimensions in Prevention
Jan. 12, 2000	Biomechanics and Injury. Analysis of the Motor Vehicle Crash Victim
Sep. 25, 1998	Overview of CIREN & Vehicle Reconstruction
Jan. 9, 1998	Crash research and the Pediatric Patient
Dec. 2, 1997	CIREN: New Technologies and the Research Connection
Nov. 13, 1997	Injury Mechanisms and Car Crashes
Sep. 16, 1997	Correlating Crash Injuries: People and Vehicles
Jun. 13, 1997	The Biomechanics of Crash Injuries
May 1997	CIREN Case Presentation and the Methods/Benefits of Linking Data
Apr. 17, 1997	A Study to Correlate Crash Data: Matching Human Injuries with Vehicular Damage
Feb. 19, 1997	CIREN: Motor Vehicle Injury Research in San Diego
Feb. 12, 1997	CIREN: Motor Vehicle Injury Research in San Diego
1997 – 2001 Monthly	CIREN Research: UCSD residents and medical students

CIREN 1998
Mediastinal Injuries

David B. Hoyt, M.D., A. Brent Eastman, M.D., Gail F. Cooper, Sharon Pacyna, R.N., M.P.H., David Guillen, B.A. and the San Diego County Trauma System

Severe mediastinal injuries of the heart and aorta remain a significant problem. They have been of interest historically for the last 500 years. Definitive repair with surgical treatment has only been accomplished in the last 40 years.

The incidence of these injuries clinically or on autopsy is highly variable depending on the presence of chest trauma, but at-scene mortality in recent autopsy series continues to account for between 30% and 50% of scene deaths. Although some of these injuries reach the hospital, their time-to-death is early if untreated and the diagnosis despite newer modalities remains challenging. Overall survival of heart injuries presenting to trauma centers with vital signs is approximately 50%. Twenty to thirty percent of transected aortic injuries still die in trauma centers prior to diagnosis.

Because they are a common cause of scene death and continue to be a diagnostic challenge with a narrow window for intervention and high surgical mortality, mediastinal injuries remain an ideal opportunity for effective prevention.

Review of San Diego CIREN cases revealed an 11% incidence of injuries to the heart and aorta with blunt rupture of the heart and aortic transection being most common. Similar cases were searched for in the CIREN database. They were compiled and analyzed for crash type, association of chest injuries and evidence of specific injury mechanisms.

Multiple mechanisms for blunt heart injury have been postulated. Review of the current data suggests that at high velocity with frontal crashes, restraint devices themselves, or the overpowering of restraint devices, continue to produce these devastating injuries. Redistribution of the load of restraints more laterally may possibly lead to a change in the frequency of these injuries.

Similar to heart injuries, multiple mechanisms have been invoked to explain aortic transection. Review of current cases suggests that during high-energy transfer, chest wall compression, either by restraints or overpowering of restraints, continues to lead to higher chest loading and injury. Redirection of energy transfer to lateral loading may potentially lead to a different incidence of these injuries.

With drivers increasingly traveling at higher speeds, reconsideration of more effective restraints may be necessary to prevent these injuries.

University of Michigan at Ann Arbor CIREN Center

CIREN Program Report

Michigan, 2001

University of Michigan Survival Flight helicopters evacuating injured patients from a crash scene.

The University of Michigan CIREN Center is situated within one of the leading biomedical research centers in the world, the University of Michigan Medical Campus Health System. The Ann Arbor-based Center has also benefited from the expertise in injury biomechanics and crash investigation within the Biosciences Division of the University of Michigan Transportation Research Institute (UMTRI), where research in injury causation and motor-vehicle crash investigations has been conducted for more than thirty years. It is also uniquely situated in close proximity to the automobile industry and its major seat and restraint-system suppliers, so that the safety engineers who design today's occupant protection systems can participate first hand in the review and analysis of crashes selected for in-depth investigations. These two features have enabled the UofM CIREN center to perform high-quality crash investigations in a timely manner, and to analyze crash and injury data with a unique and comprehensive understanding of the biomechanics of injury and vehicle and restraint design features.

University of Michigan Transportation Research Institute

University of Michigan Health System

The Crash Injury Research and Engineering Network (CIREN) project was a major impetus for the formation of the University of Michigan Program for Injury Research and Education (UMPIRE). UMPIRE is a multi-disciplinary program dedicated to studying the effects of injury so that better means of prevention can be devised. Prior to CIREN's inception, multiple researchers throughout the University of Michigan had extensive investigational activities touching on specific aspects of motor vehicle safety. However, these researchers generally focused their activities within their individual scientific disciplines of engineering, public health, or medicine. The newly created CIREN project required a multidisciplinary approach that combined expertise from all of these fields as well as others. It also required that academic researchers work with law enforcement, emergency medicine providers, safety advocates, and government regulators in addition to researchers, designers, and engineers from industry. UMPIRE was created to bring these groups together, as well as other parties with a common interest in motor vehicle safety. By helping to bridge these groups, the University of Michigan team could better conduct its CIREN research activities while at the same time enhancing collaborations outside of CIREN for the purpose of improving public safety.

Discussion of vehicle kinematics during a case review

Today, the University of Michigan Program for Injury Research and Education is comprised of a diverse group of individuals from many backgrounds and fields of expertise. The core team includes:

Stewart Wang, MD, PhD,
Director, UMPIRE
Associate Professor of Surgery,
Director of Research – Trauma Burn Center,
Principal Investigator of CIREN, Michigan.

Carla Kohoyda-Inglis, Database Coordinator

Terri Kennedy, RN, Injury Research Coordinator

June Lee, MPH, Research Associate

Sandy Lemkin, Project Coordinator

Alice Yan, MS, Database Analyst & Statistician

Elizabeth Link, Administrative Assistant

Pam Snyder, Surgical Technician

Martin Lambrecht, Johnson Controls/UMPIRE Fellow

Stephen Fuks, Visteon/UMPIRE Fellow

UMPIRE has been assisted from the beginning by a team from the University of Michigan Transportation Research Institute (UMTRI). The Biosciences Division at UMTRI has been conducting crash investigations and research for more than 35 years. Our UMTRI team includes:

Lawrence Schneider, MS, PhD,
Director of Biosciences Division,
Co-Investigator of CIREN

Joel MacWilliams, Senior Crash Investigator

Dale Halloway, Crash Investigator

Tim Compton, Crash Investigator

Jamie Moore, Crash Investigator

Chris VanEe, PhD, Assistant Research Scientist

John Melvin, UMTRI Consultant

UMPIRE draws upon the extensive knowledge and experience of the University of Michigan Medical School Faculty. Regular participants in UMPIRE activities include:

James Goulet, MD, Orthopedic Surgery,
Director of Orthopedic Trauma

Hugh Garton, MD, MHsc, Pediatric Neurosurgery

Daniel Remick, Jr., MD, Pathology,
Director of Autopsy Service

Curtis Hayes, MD, Radiology,
Director of Bone Imaging

Ella Kazerooni, MD, Radiology,
Director of Chest Imaging

David Fessell, MD, Radiology

David Marcantonio, MD, Radiology

Smita Patel, MD, MRCp, Radiology

Wendy Wahl, MD, Trauma Surgery

Mary-Margaret Brandt, MD, Trauma Surgery

Glen Franklin, MS, MD, Trauma Surgery

CIREN case reviews address the obvious void between testing or validation with the ATD's (with specified sizes, weights and vehicle positions) and the biomechanics using cadavers (tend to be elderly, female, etc). The driver/passengers within the vehicle interior are not rigid and motionless but in constant fluid motion. The ATD's and biomechanical testing can not possibly address every possible scenario, however, the CIREN cases fill some of the gaps and can provide direction.

—an automotive engineer

UMPIRE also draws regularly on the expertise of professionals from local government:

Bader Cassin, MD, Chief Medical Examiner for
Washtenaw and Livingston Counties

Carl Hein, EMT, Director, Education Division,
Ann Arbor Fire Department

Mark Luick, Ann Arbor Fire Department

RESEARCH

As the Michigan CIREN Center, one of our primary aims is to collect data for the CIREN National Database. We recruit an average of fifty cases per year to analyze and enter into the database. These cases are the backbone of the crash injury research at UMPIRE. After extensive preparatory investigations by individual team members, we gather the entire team together once a month to take on the work of forensic investigators and determine the mechanisms by which injuries to study subjects were caused during their motor vehicle crash. Given our location and close proximity to large concentrations of automotive engineering and testing expertise, our center is unique in its ability to enlist the assistance of engineers who have first-hand knowledge of the vehicles involved in our analysis of the vehicle's interaction with the occupant during the crash. Although it is not possible to determine with absolute certainty the exact way a specific injury was caused, great effort is spent to determine the several most likely scenarios based on all the evidence gathered as well as the combined analytical expertise of the medical, biomechanical, crash investigation, and vehicle engineering expertise present. Once the causation mechanism for an injury is determined, that information is entered into the CIREN database so that it is accessible to automotive engineers.

> *The case reviews keep me from getting complacent about safety. When dealing with specifications and standardized crash tests, you get used to running an experiment in which many factors are controlled (impact speed, PDOF, seat position, occupant stature, etc.). The case reviews show that nothing is fixed or set in real-life crashes, and they force automotive engineers to go look at what the variables were and how they influenced the crash outcome. In a standardized crash test, there are certain things to look for; after my first case review, I realized that there are other things I should also consider; and each subsequent CIREN case has only added to this understanding.*
>
> —an automotive engineer

From the large body of data that we have gathered for the CIREN project, several areas have been of particular interest for our group:

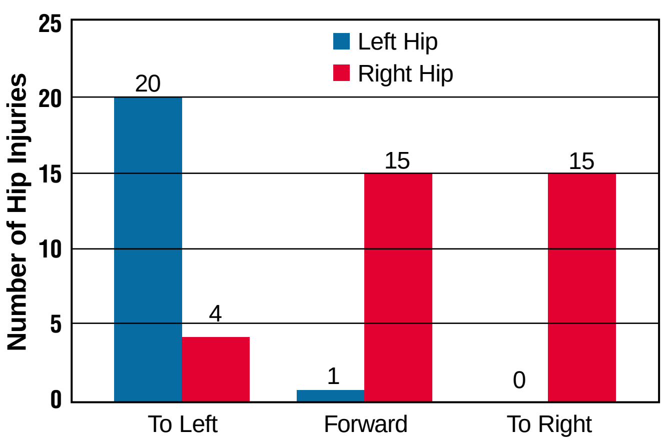
Biomechanics of Hip and Thoracic Injuries

One of the primary differences between a CIREN crash investigation and investigations conducted by other programs such as the National Automobile Sample Systems (NASS), is that each CIREN case is based on a "case occupant" who has been admitted to a level-1 trauma center due to injuries, or suspected injuries, sustained in the crash. Because of this, accurate and detailed injury data, including medical records and images, are available for the case occupant. These detailed injury data are used, along with detailed crash and vehicle-damage data and direct input from treating and diagnosing physicians, in determining occupant kinematics and injury causation. Thus, CIREN investigations include information about the specific types and locations of skeletal and soft-tissue injuries, as well as information about pre-existing medical conditions that may have contributed to those injuries. While such information is not necessary for many types of analyses, these detailed injury data significantly increase the utility of real-world crash-investigation data to biomechanical researchers. For example, specific images and information of a fracture to the mid-shaft of a long bone can be used to determine if the bone fractured in bending, in axial compression, in twisting, or in shear, and can thus provide clues to the manner in which the limb was loaded in a crash. Such detailed injury data from the UofM CIREN cases are being used in two areas of biomechanical injury research at UMTRI – 1) hip fractures and dislocations, and 2) thoracic injuries.

> *By being able to cite the high incidence of leg injuries, there is evidence to go to the product design teams and work on designing a better restraint system to help prevent these types of injuries.*
>
> –an automotive engineer

With the success of increased belt use rates and airbags in frontal crashes, the UofM CIREN center admits many victims of severe frontal crashes who have relatively minor injuries to the head, face, neck chest, and abdomen, but who have sustained life-time disabling injuries to the lower extremities. Among these lower-extremity injuries, fractures and dislocations of the hip joint are over represented in the UofM CIREN cases. These injuries are occurring to both belt-restrained and unbelted front-seat occupants of late model vehicles involved in frontal crashes that are similar in severity to those conducted for federal safety testing. This has led to the initiation of a new biomechanical effort at UMTRI to investigate human tolerance to, and causal factors involved in, hip injuries due to impact loading through the knees. Analysis of the crash conditions under which these hip injuries occur in UofM CIREN cases has led to the observation shown in the chart below that the injured hip is almost always on the side of the body to which the occupant moved during the frontal crash due to the location and direction of the impact (i.e., due to the principal direction of force for the case vehicle). This suggests two possible factors involved hip injuries that are being explored further in biomechanical testing – 1) that adduction of the hip joint during knee loading reduces the area of contact of the femoral head on the posterior wall of the acetabulum, thereby reducing the tolerance to fracture and dislocation, and/or 2) that the knee/thigh/hip complex on the side to which the body moves is loaded more than on the uninjured side. To study these and other factors that may contribute to the increased likelihood of hip injury in frontal crashes, controlled laboratory tests with human surrogates are being conducted at UMTRI. Detailed data on hip and pelvic fractures in frontal crashes from the UofM CIREN database are being compared to injuries obtained in these laboratory tests, and provide the basis for validating the laboratory test conditions.

Direction of Occupant Movement based on Principal Direction of Force (PDOF)



In a similar manner, UofM CIREN researchers are using the detailed injury data from the CIREN cases to examine injury patterns of skeletal and visceral thoracic injuries. In particular, CIREN researchers are documenting the specific circumferential and vertical locations of rib fractures from frontal and lateral loading and from different types of restraints and objects (belts, airbags, door interiors, etc.). The results should help interpret and validate thoracic injuries obtained from laboratory testing using human surrogates, and should provide useful information for determining the way in which the torso was loaded in real-world crash investigations. Preliminary findings suggest that the patterns of skeletal injuries in living persons can be quite different from those obtained in laboratory testing, and that, unlike testing with human surrogates, are usually accompanied by significant visceral injuries. The results also suggest that the locations of rib fractures can vary significantly for different occupants exposed to similar loading conditions.

Finally, detailed information on the locations and nature of aortic ruptures to occupants of frontal and near-side impacts in CIREN are being compiled from CT images. The results are being used to validate research methods of experimental testing and computer modeling aimed at determining the specific mechanisms of these vascular injuries that are almost always fatal.

Elderly

There are more than 25 million people age 70 years and older in the United States. In 2000, this age group made up 9.2 percent of the total U.S. resident population, compared with 8.5 percent in 1990. From 1990 to 2000, this older segment of the population grew nearly twice as fast as the total population.

There were 18.5 million older licensed drivers in 1999 (2000 data not available)—a 39 percent increase from the number in 1989. In contrast, the total number of licensed drivers increased by only 13 percent from 1989 to 1999. Older drivers made up 10 percent of all licensed drivers in 1999, compared to 8 percent in 1989.

In 2000, 181,000 older drivers were injured in traffic crashes, accounting for 6 percent of all the people injured in traffic crashes during the year. These older drivers made up 13 percent of all traffic fatalities, 12 percent of all vehicle occupant fatalities, and 17 percent of all pedestrian fatalities.

Better health and longer life expectancy will mean a greater mobility for older drivers. All of these factors will increase the traffic exposure of older drivers in terms of the number of miles driven per year.

Changing U.S. Demographics by Age Group

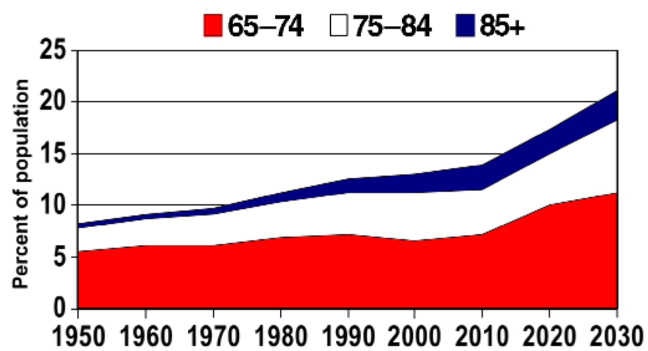
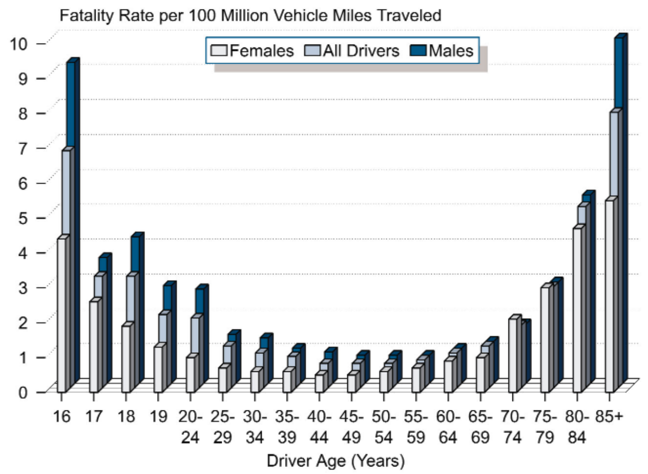


Chart clearly shows trend toward an older population

Detailed medical analysis of real-life crash cases at our center shows that while total injury rates are higher in elderly motor vehicle crash (MVC) occupants than younger MVC occupants, there are significant differences in their respective injury patterns, particularly in the torso. In our studies examining the outcomes of real-life MVCs, we have found that elderly occupants are much more susceptible to injuries to the thoracic region where we have noted increases in both the incidence and severity of injuries. In contrast, we have noted decreases in both the incidence and severity of abdominal injuries with aging. We have also noted a decrease in the incidence of brain and lower extremity injury by age, but an increase in severity. Efforts are currently underway at UMPIRE to determine in greater detail how and why injury patterns change with the aging of the

Driver Fatality Rates by Age and Gender, 1996



population. The diverging vulnerability of different body regions to MVC injury with aging suggests that the ability of different body regions to tolerate blunt trauma may change differentially with aging.

Body Composition – Effect on Injury Tolerance

For the past several decades, vehicle safety systems have been developed based on various criteria measured by crash dummies that are designed to represent an idealized occupant of fiftieth percentile height and fiftieth percentile weight with the tissue properties of a 45-year-old. There has been scant attention paid to age effect or the effects of differences in body composition. In the construction of a vehicle, the frame or chassis is necessarily the strongest and stiffest part of the vehicle. In this way, the frame plays a role similar to the skeleton of the body, which forms a scaffold for the soft tissues and viscera of the body. Other structures in a vehicle are made of sheet metal, making them less stiff and more prone to deformation or damage when subjected to crash forces.

CT Scan Images

Male, 183 cm, 85 kg
Age = 38 years

Male, 183 cm, 80 kg
Age = 79 years

"Computed tomography scan of the pelvic region demonstrates that different components of the body (BONE - white, MUSCLE – gray, FAT – dark gray) change with increasing age. Muscle mass, bone mass, and bone density decrease with aging. In contrast, fat mass increases.

We cannot use live subjects to experimentally determine the effect of age and body composition differences on injury tolerance in crashes. However, with tremendous improvements in medical imaging technology over the past decade, we can now capture body composition data in precise anatomic detail. Computed tomography (CT) scans are the evaluative method of choice for blunt polytrauma. The cutting edge CT scans available at the University of Michigan Medical Center capture precise details about the injuries as well as the patient's baseline body composition. Studies are currently underway to determine how alterations in body composition (bone density, fat, and muscle distribution) affect injury tolerance. We anticipate that these studies will provide valuable information that can be used to tune vehicle safety systems to each individual occupant so that crash safety can be maximized.

Case reviews are valuable in that the open discussions, the various crash vehicles and conditions as well as the medical input will undoubtedly lead to safer designs. Typically, engineers look at data from test dummies and simulations. To be able to discuss and analyze what are real world situations with colleagues from competitor companies has heretofore not been an option. I look forward to continued participation.

—an automotive engineer

EDUCATION

As our name states, the second major aim of UMPIRE is education. The first aim, research, is necessary to better understand how and why injuries take place. However, improved knowledge gained from research is useless unless it is applied practically. Education is the essential counterpart to research that transmits knowledge to those who can apply it usefully. Insights from our multidisciplinary research activities are actively transmitted back to UMPIRE participants and their sponsoring organizations so that improvements in vehicle safety and trauma care can be better effected. At the same time, we have dedicated great effort to educating the general public. Education is the first step to prevention. UMPIRE team members have taught elementary school classes about the importance of using booster seats and seat belts properly. We are currently in the process of developing a curriculum that will be taken to elementary schools throughout the region with the assistance of volunteers from the University of Michigan and financial support from corporate sponsors.

UMPIRE Researchers speak to a local multi-age classroom

The data from CIREN provides the most current information available regarding injuries caused by motor vehicle crashes. Changes are constantly taking place within the population as well as the vehicle fleet. As a result, injury patterns change as well. Findings and insights from CIREN can help emergency medical service providers and physicians more rapidly diagnose and treat life-threatening injuries. We have relayed our CIREN findings on a constant basis to local, regional, and national medical groups. Within the medical center, UMPIRE team members have given numerous lectures to nurses, medical students, and surgical residents. In addition, team members have highlighted case presentations at the weekly trauma conference at the University of Michigan as well as other area hospitals. Insights and case presentations from CIREN have been made at local and regional EMS and Emergency Medicine conferences as well as trauma conferences for physicians and allied health personnel. Multiple presentations have been made at national public health and surgical meetings. CIREN findings from Michigan have also been presented in England and Sweden.

We feel it is important that the people who directly influence the development of vehicles be engaged as much as possible. From the beginning, engineers from GM (our initial sponsor) were invited to participate in our monthly case review meetings. Subsequently, we opened our meetings to other auto manufacturers as well as their suppliers. Since that time, we have had safety engineers and other representatives from the following companies attend: Aeroteck Scientific Staffing, Autoliv, Breed Technologies, Daimler-Chrysler, Delphi Automotive, Dow Automotive, Ford Motor Company, Johnson Controls, Polymer Solutions, Inc. (GE Plastics), Nissan, Toyota, TRW, and Visteon. During these monthly case review meetings, we place great emphasis on cross-education of the many scientific disciplines present. Time is set aside to teach medical

CIREN Public Meeting in Ann Arbor, September 2001

concepts to the engineers and vice versa. Visiting professors, alternating between medical and engineering specialties, are invited to present teaching seminars as part of our case review meetings. The interest and support from the automotive engineering and medical communities has been overwhelming. Attendance at our monthly case reviews exceeds the room capacity of forty and is standing room only.

I believe the biggest impact came from the UMPIRE / CIREN Team presentation last summer. Most of our engineers never deal with vehicle safety / crash testing themselves, they only see the specifications. They walked away more aware that "this is what an accident really looks like" and I think they were able to associate pictures and outcomes with the numbers and formulas.

–an automotive engineer

As important as the case reviews are, we are limited by space and time constraints. To this end, we have traveled to several companies in an effort to bring the case reviews and their resultant insights to a larger number of automotive engineers. The UMPIRE team has given presentations at GM, Ford, Chrysler, Johnson Controls, and Visteon. Although it is not a true case review with the exchange of ideas that is usually present, it gives a larger audience an idea of what comes out of case review and the importance of having many people from different disciplines participate.

UMPIRE Injury Research Fellowship

Lead-time is needed to design, test, and manufacture safety systems and vehicles. Any delay in getting data and insights back to the engineers degrades the usefulness and relevance of the information. Time is, therefore, of the essence in analyzing and sharing data. The mass of data collected by CIREN needs to be sorted and organized in a

Multidisciplinary group at a case review

way that makes it useful to the automotive engineers who will be using this information to improve vehicle design. The UMPIRE team takes special care to avoid introducing bias during the collection process or reducing the granularity of the data. We feel that the engineering end users are necessary participants in the process. Medical and engineering specialists both have much to learn from the other with regards to injury causation and prevention in motor vehicles. Both sides have pieces of a puzzle that they have been trying to put together without the other. Without working together, the quality of the data and of its analysis will not improve. We determined that the best way to have medical and engineering specialists learn from each other while working together was to put them side-by-side in a combined fellowship program.

UMPIRE Fellows and staff get hands-on occupant extrication training

Since UMPIRE initiated the fellowship program in April 2001, our inaugural fellows have had the opportunity to go out with our crash investigators to examine the crash scene and vehicle prior to reconstructing the events of the collision. In conjunction with this, they have had the chance to examine the occupant's medical records and studies. By observing the gathering of case data from start to finish, they have a better appreciation of the strengths and limitations of data in the CIREN database. The Fellows have attended surgical operations and autopsies as well as a series of lectures given by our affiliated medical and engineering staff. They have been taught the principles of rescuing entrapped occupants by firemen and had the opportunity to try it first-hand. A fellowship is an optimal way for someone already trained in a field to gain the additional expertise necessary to tackle a specialized problem. Fellows differ from students in that they already have expertise in their general field. Fellows need real-life problems to work on rather than hypothetical exercises; they need hands-on training rather than classroom learning. Any improvements we make in the expertise of our engineering and medical fellows will improve the quality of our mutual research and make advances in automotive safety design and medical treatment possible. This improved expertise will enable the engineering fellows to better support the mission of their companies and enable medical fellows to better support the patient care mission of their institution. At the same time, the enhanced mutual understanding fostered by this close collaboration and training will improve the quality of data coming from our center and all CIREN centers.

Information from the case reviews serves as another data point to assist in decision making when trying to design and optimize, as much as possible, a restraint system.

–an automotive engineer

SUMMARY

The work coming from the CIREN centers around the country is valuable. At UMPIRE, we feel a strong sense of urgency to disseminate this information to the people who can effect the most change in automotive design and safety. We have committed ourselves to providing a forum for individuals from many disciplines to exchange ideas and opinions. At the same time, we are actively educating everyone from EMTs to medical personnel to automotive engineers to school age children about safety and prevention. It is, in the end, about people.

Selected Extramural Presentations

"Crash Injury Patterns in Elderly Motor Vehicle Occupants." Trauma Conference. University of California, San Diego. February 1999.

"Prevention of Injury Through Automotive Engineering." Trauma Care 1999. A Focused Review. Ypsilanti, Michigan. February 1999.

"Injury Outcomes in Crashes Involving Chrysler Vehicles." Auburn Hills, Michigan. February 1999.

"Crash Injury." EMS Expo 1999. Grand Rapids, Michigan. April 1999.

"Motor Vehicle Crash Injury." Academy of Surgery of Detroit. Detroit, Michigan. April 1999.

"Mechanisms and Outcomes of Injuries to the Knee-Femur-Hip Complex." National Highway Traffic Safety Administration. Washington, DC. May 1999.

"Injury Patterns and Causation Mechanisms." Regional Extrication Learning Symposium and Team Challenge. Farmington Hills, Michigan. June 1999.

"Injury Patterns and Mechanisms in Motor Vehicle Crashes." Surgery Grand Rounds, University of Pittsburgh. Pittsburgh, Pennsylvania. June 1999.

"An Aging Population: Fragile * Handle with Care." CIREN public meeting. Ann Arbor, Michigan. September 1999.

"Patterns and Mechanisms of Injury in Motor Vehicle Crashes." William Beaumont Medical Center. Royal Oak, Michigan. October 1999.

"Maxillofacial Injuries in North American Vehicle Crashes." British Trauma Society Annual Meeting. October 1999.

"Injury Patterns and Outcomes in Elderly Motor Vehicle Occupants." Third CIREN Annual Conference. San Diego, California. October 1999.

Child safety seminar. "Medical considerations for injury prevention among small children involved in motor vehicle crashes." Children's Museum of Los Angeles. Los Angeles, California. January 2000.

Child safety seminar. "Medical considerations for injury prevention among small children involved in motor vehicle crashes." Children's Museum of Chicago. Chicago, Illinois. February 2000.

"Mechanisms of Blunt Trauma in Motor Vehicle Crashes. Trauma 2000 Symposium." St. Joseph's Mercy Medical Center. Ann Arbor, Michigan. February 2000.

"Current Progress in Trauma Burn Research." Ford Motor Corporation Physicians Worldwide Visit to Ann Arbor. Ann Arbor, Michigan. March 2000.

Child safety seminar. "Medical considerations for injury prevention among small children involved in motor vehicle crashes." Children's Museum of Manhattan. New York, New York. April 2000.

"Emerging Patterns in Acetabular Fractures Following Motor Vehicle Crashes." CIREN Quarterly Conference. Washington, DC. May 2000.

"The Small Child in a Frontal Car Crash: Medical Considerations." Volvo Safety Center. Gothenburg, Sweden. July 2000.

"NASS Based Investigation of Obesity and Injury Severity in Motor Vehicle Crashes." American Pubic Health Conference, Injury Control and Emergency Health Services Poster Session. Boston, Massachusetts. November 2000.

"Torso Injury Patterns in Motor Vehicle Crashes." Trauma 2000. Annual Congress of the Scandinavian Trauma Society. Gothenburg, Sweden. November 2000.

"Emerging Patterns of Thoracic Injuries in Motor Vehicle Crashes." CIREN Quarterly Conference. Washington, DC. December 2000.

"Human Injury Data for Safer Vehicle Design: Lessons from Real Life an the Laboratory." Global Automotive Safety Conference. Society of Plastic Engineers. Southfield, Michigan. February 2001.

"Occupant Injury Patterns and Offset Frontal Collisions." CIREN Quarterly Conference. Washington, DC. March 2001

"Pediatric Injuries Associated with Specific Types of Restraint Misuse." 5th Annual International Child Passenger Safety Technical Conference Technical Issues, Standards and Regulation Workshop. Indianapolis, Indiana. June 2001.

"Patterns of Skeletal and Visceral Thoracic Injuries in Frontal and Near-Side Impacts." Moses Gunn Surgical Research Conference, Ann Arbor. June 2001

"Crash Injury Data for Automotive Engineers: Lessons from Real Life." CIREN quarterly conference. Washington DC. June 2001

"Human Injury Trends Driving the Next Generation of In-Vehicle Electronics." Intelligent Vehicles Conference. Chicago. July 2001

"Crash Injury Research. Emergency Medicine Grand Rounds." Ann Arbor, MI. August 2001.

"Crash Injuries and SUVs: Michigan Case Presentations." CIREN quarterly conference. Ann Arbor. September 2001.

"Detailed Injury Analysis of Knee, Thigh and Hip injuries in Frontal Motor Vehicle Crashes." American Public Health Conference, Injury Control and Emergency Health Services Poster Session, Atlanta. October 2001.

Publications:

Wang SC, Schneider L. "An Aging Population: Fragile – Handle with Care." *Proceedings of the National Highway Traffic Safety Administration*, 1999.

Wang SC. Invited Commentary: "Today's CIREN: News you can use." *Annals of Emergency Medicine.* 38(2): 182-3, 2001

Patel NN, Wang SC. "Arterial dissection injury following motor vehicle collision." *J Trauma.* In Press.

Siegel JH, Loo G, Dischinger PC, Burgess AR, Wang SC, Schneider LW, Grossman D, Rivara F, Mock C, Natarajan GA, Hutchins KD, Bents FD, McCammon L, Leibovich E, Tenenbaum N. "Factors influencing the patterns of injuries and outcomes in car versus car crashes compared to sport untility, van or pick-up truck versus car crashes: Crash Injury Research Engineering Network Study." *J Trauma.* In Press.

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Tencer A, Kaufman R, Ryan K, Grossman D, Henley B, Mann F, Mock C, Rivara F, Wang SC, Augenstein J, Hoyt D, Eastman B. "Femur fractures in relatively low speed frontal crashes: The possible role of muscle forces." *Accident Analysis and Prevention*. Submitted.

Wang SC, Schneider LW, Alarcon WH, Knight KM, Kohoyda-Inglis CJ, Macwilliams, JB, Pucci PS, Augenstein JS, Burgess A, Cooper G, Dischinger P, Eastman AB, Grossman D, Hoyt DB, Loo G, Rivara F, Siegel JH, Elliot D, MuCullough C, Brown L. "High incidence and morbidity of rib fractures in elderly motor vehicle crash occupants." *J Trauma*. Submitted.

Patel NN, Wang SC, Marentette L. "A complex and unusual penetrating injury of the cheek requiring skull base exploration." Submitted.

Abstracts

Alarcon WH, Klein RD, MacWilliams J, Pucci P, Taheri P, Dries D, Schneider L, Wang SC. "Comparison of Outcomes of Passenger-Sedan Occupants from Near-Side Impacts by Sport Utility Vehicles and Pickup Trucks." *Proceedings of the 58th Annual Meeting of the American Association for the Surgery of Trauma*, 1998, 180.

Wang SC, Schneider L. "An Aging Population: Fragile – Handle with Care." *Proceedings of the Crash Injury Research Engineering Network Conference*. 1998.

Brookes C, Wang SC, MacWilliams J. "Maxillofacial injuries in North American vehicle crashes." *Proceedings of the British Trauma Society Annual Meeting*, 1999.

Orzechowski KM, Lee JH, Eichelberger MR, Wang SC. "Pediatric injuries associated with specific types of restraint misuse." *Proceedings of the International Child Passenger Safety Conference*. 2001.

The Mercedes-Benz CIREN Center at the University of Alabama at Birmingham

CIREN Program Report

The Mercedes-Benz CIREN Center is located at the University of Alabama at Birmingham. The University of Alabama at Birmingham (UAB) Health System is one of the largest and most diverse providers of health care, research, and education in the Southeast. With 908 beds, the UAB Hospital is the largest tertiary care institution in Alabama. UAB trains most of Alabama's physicians, nurses, dentists, optometrists, and allied health professionals.

The state of Alabama has one of the highest death rates resulting from automobile accidents in the Nation. The University of Alabama at Birmingham Hospital serves a six county region with a population of approximately 2.1 million. The Level 1 Trauma Service treated more than 7,000 trauma-related injuries last year with 1,800 admissions. The trauma facility specializes in the treatment of burns, as well as head injuries, pelvis fractures, and multi-system injuries. UAB's Burn Center admits more than 200 patients per year and is the only American College of Surgeons/American Burn Association verified burn center in the state. The Mercedes-Benz CIREN Center is only one of several research initiatives focused on injury prevention housed in the Center for Injury Sciences at UAB.

The Mercedes-Benz CIREN Center was established in April 1999 as the 8th CIREN center. It was the first center voluntarily funded by a private sector partner. It is jointly funded by DaimlerChryslerAG (DCAG), Mercedes-Benz U.S. International, Inc. (MBUSI), and Mercedes-Benz USA, Inc. (MBUSA) to advance research on the causes of auto-related injuries and casualties. A very close and productive relationship has evolved between the Mercedes-Benz CIREN Center team and Mercedes-Benz safety engineers.

The Mercedes-Benz CIREN Center Team

The Mercedes-Benz CIREN center is directed by **Loring W. Rue, MD.** Dr. Rue obtained his undergraduate and medical degrees at the University of Virginia in Charlottesville. He undertook his residency in General Surgery at the University of Alabama at Birmingham and pursued a clinical and research fellowship at the U.S. Army Institution of Surgical Research in San Antonio. During that time, he conducted both clinical and basic research investigations concerning shock and burn resuscitation. In January 1992, Dr. Rue returned to the faculty at the University of Alabama at Birmingham and is currently Professor of Surgery. He also holds secondary appointments in the Department of Anesthesiology and Department of Civil and Environmental Engineering. He has held several administrative positions relative to trauma and surgical critical care as well as having been actively involved in the undergraduate and graduate medical education programs at UAB. His major research interests include the CIREN program and related epidemiologic research and trauma system development.

Other key participants of the Mercedes-Benz CIREN Center include **Drs. Jorge Alonso, Stephan Moran, Donald Reiff, Gerald McGwin, Alan Eberhardt, Gregory Davis, Jim Davidson, Mr. Daniel Selke, Ms. Marilyn Doss, Ms. Holly Waller, and Ms. Ashley Davis**.

Dr. Jorge Alonso is an Associate Professor of Surgery and Biomedical Engineering at UAB. He is also the chief of Orthopaedic Trauma at University Hospital and serves as the Associate Director for Clinical Diagnosis of the Center for Injury Sciences. Dr. Alonso's clinical practice is in the treatment of difficult fractures, with a special interest in fractures of the pelvis and acetabulum. His extensive clinical experience has resulted in multiple publications.

Dr. Stephan Moran is the newest addition to the Mercedes-Benz CIREN Center team and is an Assistant Professor in the UAB Department of Surgery, Section of Trauma, Burns and Surgical Critical Care. Dr. Moran's research interest is in identifying the etiology and mechanisms of human injury as a result of blunt and penetrating forces. Dr. Moran is presently working on several projects looking at the association between occupant injury patterns in motor vehicle collisions with motor vehicle design and deformation patterns.

Through the first two years of CIREN activities at UAB, **Dr. Donald Reiff**, was an invaluable component of the team. Dr. Reiff's involvement was very productive as can be noted by his contributions to recent presentations and publications. Having completed the research phase of his training, Dr. Reiff has returned to the clinical aspect of his general surgery residency.

Dr. Gerald McGwin is an Assistant Professor in the Department of Epidemiology and Department of Surgery, and is the Associate Director for Research of the Center for Injury Sciences. Dr. McGwin's research focuses on injury and trauma, particularly among older adults. He is working on several projects related to medical and functional impairments and driving.

Dr. Alan Eberhardt is an Associate Professor in the UAB Department of Biomedical Engineering, with secondary appointments in Materials and Mechanical Engineering and in Civil Engineering. He is the Director of the UAB Musculoskeletal Mechanics Laboratory and directs both graduate and undergraduate research in biomechanics. For several years, Dr. Alonso and Dr. Eberhardt have partnered in investigating the etiology of pelvis ring and acetabular fractures from frontal, offset, and side impact crashes. A summary of current research being conducted by Drs. Alonso and Eberhardt is provided below.

Dr. Gregory Davis is a board certified forensic pathologist, an Associate Coroner with the Jefferson County Coroner/Medical Examiner Office (JCCMEO) and Associate Professor of Pathology at UAB. His interest is in adding to the UAB CIREN program the information gathered by postmortem examination of MVC occupant fatalities. A description of the recently formed partnership between the Mercedes-Benz CIREN Center and the Jefferson County Coroner/Medical Examiner Office is provided below.

Dr. Jim Davidson's primary appointment is as an Assistant Professor in the Department of Civil and Environmental Engineering at UAB. He also has appointments with the Department of Surgery and the Department of Biomedical Engineering and is faculty of the University Transportation Center for Alabama. His research and teaching centers around the use of advanced modeling techniques for describing mechanical and structural behavior. As the Associate Director of the Mercedes-Benz CIREN Center, Dr. Davidson helps with all aspects of the CIREN activities, plus he is helping to build other collaborations between the School of Engineering and School of Medicine and to build capabilities needed for a comprehensive crash injury research program that includes a strong engineering component.

Daniel Selke is the Manager of Safety Engineering for Mercedes-Benz USA, Inc. Mr. Selke participates in the CIREN case review meetings and provides very valuable insight into the design of automotive safety features and upcoming technologies.

Marilyn Doss is the crash investigator for the Mercedes-Benz CIREN Center. She has over 15 years of experience with the National Automotive Sampling System program and the General Estimates System.

Holly Waller serves as study coordinator for the Mercedes-Benz CIREN Center. She is a registered nurse and received her bachelor's degree in nursing from Auburn University in 1992.

Ashley Davis has recently joined the team as the Data Information Coordinator in which she primarily assists in collecting CIREN data and preparing for case reviews.

Progress and Accomplishments

As of November 2001, the Mercedes-Benz CIREN Center team has screened 975 patients for enrollment since investigating its first case in November 1999. 84 cases have so far been enrolled. Each case is first organized and carefully reviewed in a meeting of the core UAB team, and then is presented formally to an extended group comprised of additional trauma specialists, orthopedic specialists, EMS providers, biomedical engineers, automotive safety engineers, etc. This group of disparate, yet vast expertise analyzes each case and agrees on the most likely injury mechanisms. More than a dozen formal case review meetings have occurred. Also, UAB has participated in joint meetings with other CIREN centers and has hosted meetings with the Baltimore CIREN team and the Michigan CIREN team to share experiences and methodology.

The team has presented their work at several CIREN conferences and other professional conferences and meetings. Quarterly CIREN conference presentations include: "Case Study of Lower Extremity Fractures" (May 5, 2000), "Clinical, Biomechanical, and Epidemiologic Perspectives on Side Impact Crashes" (July 21, 2000), "Gender Differences in Below Knee Fractures Following Offset Frontal Collisions" (March 16, 2001), "Passenger Cars, Minivans, and SUVs - An Exploratory Study in Relative Injury and Fatality Rates" (September 6, 2001).

In addition to the CIREN conferences, the team has presented their work at several other conferences and meetings as part of their outreach activities. This includes presentations to nurses and EMT's at the Annual Trauma Symposium, to the Emergency Nurses Association Injury Prevention Conference, and to the Alabama Transportation Conference. Now that the surveillance and data gathering activities of the Mercedes-Benz CIREN Center team are well established, the team plans to increase its use of CIREN in outreach activities.

Student Involvement

As part of the UAB Center for Injury Sciences (CIS), the Mercedes-Benz CIREN Center has had the opportunity to involve medical students and residents in its activities. Each year at least one resident in general surgery participates regularly in the collection and interpretation of data collected as part of a CIREN investigation and review. Recently, the Center's involvement with medical students has grown. Most often these students are responsible for investigating hypotheses about injury patterns in motor vehicle collisions that are generated from individual CIREN cases. Working with CIS staff, these students address these hypotheses using databases including NASS, FARS and GES.

Students have also participated in CIREN-related activities within the School of Engineering. Both graduate and undergraduate engineering students have been involved in the biomechanical lower extremity research being conducted by Drs. Eberhardt and Alonso. Several theses and publications have resulted. Also, through funding from the National Science Foundation, National Highway Traffic Safety Administration, and the University Transportation Center for Alabama, engineering students have explored, for example, causes and mechanisms of motor vehicle crash induced head injury, causes and mechanisms of injury in children, and technology needed for an integrated system for the remote determination of injuries incurred during motor vehicle crash.

Partnerships

During 2001 two important partnerships were formed with the Mercedes-Benz CIREN Center. The first partnership was with the Associate Coroner with the Jefferson County Coroner/Medical Examiner Office (JCCMEO). It had been observed by members of the CIREN team that an important population of motor vehicle collision victims do not survive the immediate effects of the collision and thus would never come to our attention. Therefore a relationship was formed between our Center and the JCCMEO. Dr. Davis identifies individuals who meet CIREN criteria and provides access to the necessary information to conduct an investigation. Dr. Davis has also been an invaluable resource during case reviews given his extensive experience in investigating causes of death.

The second partnership that has been formed is with The Children's Hospital of Alabama (TCHA). While this relationship is still being forged, resources are presently being organized to enroll children in CIREN very soon. Dr. William Hardin, Associate Professor of Surgery, and Carden Johnston, Professor of Pediatrics, participate regularly in cases reviews and will lead the CIREN effort at TCHA.

From the very beginning, the Mercedes-Benz CIREN Center has worked to incorporate a strong engineering research component into the program. This has facilitated a strong partnership between researchers of the School of Medicine and the UAB School of Engineering. The ultimate vision is to build the ability for comprehensive, collaborative crash injury research that includes the ability to analyze occupant motion and injury sources, forces that are incurred by particular body regions, and then conduct focused biomechanics studies on injury mechanisms and tolerances. There also are capabilities and strong interest from the School of Engineering in participating in the development of intelligent transportation technologies that will reduce the incidence and severity of motor vehicle crashes, and in developing and integrating technologies for automatic crash notification and remote injury determination.

Themes/Study Focus Areas

Elderly

The elderly are the most rapidly growing segment of the U.S. population and are increasingly active. The elderly also have one of the highest crash involvement and fatality rates of all age groups. This reflects a distinct pattern of risk factors for motor vehicle collisions as well as a reduced ability to survive given a collision. Dr. McGwin focuses much of his research interests on these topics. As such, the Mercedes-Benz CIREN Center has a particular interest in enrolling older adults, even if they do not meet CIREN criteria. These cases have formed the basis for several research activities by Dr. McGwin. Many of these activities have been presented and/or published (listed below).

Lower Extremity Injuries

Automotive collisions continue to be growing source of injury to the pelvis and lower extremities. Previous experimental and computational studies in the areas of pelvic and ankle fractures have provided valuable insight into injury mechanisms and means for prevention, however, much is still unknown. Specifically, the roles of femoral angle and loading axis on acetabular and pelvic stresses, and related fractures, have not been established. The stiffness of the talocrural joint at the bone-ligament level has not been well described, and is necessary to validate current finite element models of the ankle.

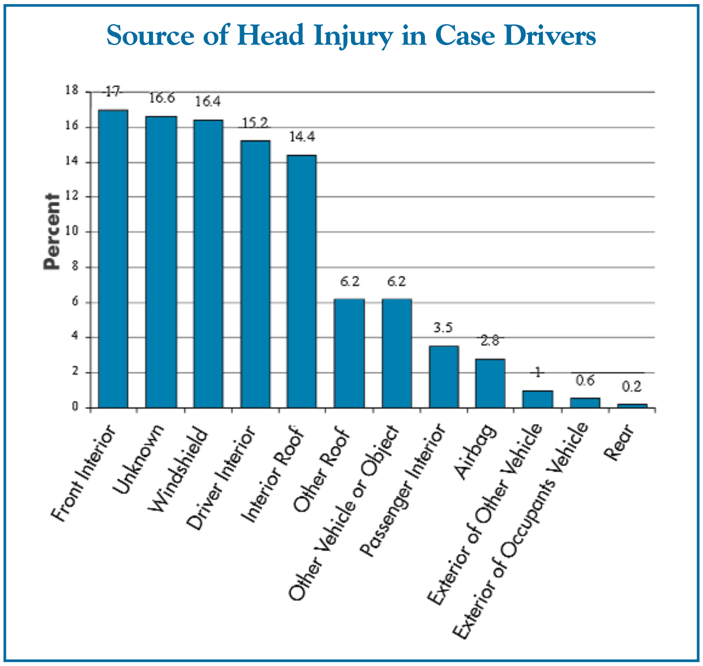
One primary aim of ongoing studies at UAB is to improve our understanding of the etiology of pelvic ring and acetabular fractures in frontal, offset and side impact automotive crashes. A combination of experimental and computational studies is being used to determine the effects of loading direction and femoral orientation on acetabular stresses, dynamic pelvic stresses and resulting fracture patterns. First, contact pressures are being measured in cadaver acetabulae using pressure-sensitive film under conditions of varying femoral angle and load path. These contact pressures will be implemented in finite element models to examine the effect of femoral angle and principal loading axis on pelvic stresses. Ultimately, select impacts will be performed in order to test the model predictions for acetabular and pelvic ring fractures.

A second objective is to determine the stiffness/flexibility behavior of the ankle at the talocrural joint. This is being done using an experimental apparatus that imposes controlled moment loading about three orthogonal coordinate axes. Rotational and translational displacements are measured on isolated cadaver ankles, dissected to the bone-ligament level, using 3-D motion capture. Nonlinear profiles of talocrural flexibility behavior will be established for validation of existing finite element models. Secondary goals for the effort include continued surveillance activities related to pelvic fractures and a gait study of subjects recovering from pelvic reconstructive surgery.

Head Injury

Head injury remains one of the leading causes of trauma related death in the United States. It is estimated by the National Institute of Health's, Integrated Head Injury Task Force in 1992 that 500,000 Americans sustain traumatic brain injury annually with an economic impact of $7.6 billion. In the Southeast, approximately 100,000 people sustain TBI each year, at a rate higher than the rest of the Nation.

UAB has been involved in developing a head injury plan for Alabama. This plan parallels the ideal trauma system that considers prevention efforts, pre-hospital care, in-hospital care, and rehabilitative concerns. An integrated catchment program for patients with head injury and other critical neurologic diseases is being developed, and data relative to all facets of care for the severely injured is being integrated and interrelated. This program supports the development of a comprehensive head injury database to involve the pre-hospital care elements from the trauma



system, the in-hospital acute care aspect provided by the TRACS® trauma registry, and the rehabilitative data supported by NIH sponsored Model Center for Traumatic Brain Injury at UAB and the UAB Injury Control Research Center/Center for Disease Control supported data set for the National Center for Injury Prevention Control. This activity also partners with the Center for Health Promotion to develop an academically oriented prevention and outreach initiative. Although airbag and other safety technology have resulted in a substantial reduction in head injury during motor vehicle crashes, head injury remains a leading cause of death and long-term disability of motor vehicle crash victims. Since motor vehicle crashes account for over 70,000 serious head injuries each year, the ongoing head injury efforts are being partnered with the UAB CIREN efforts to specifically study causes and mechanisms of head injury occurring in crashes in today's fleet.

Research Efforts/Publications/Submissions

Although the Mercedes-Benz CIREN Center at UAB has been collecting cases for only a couple of years, the activities of the center have already led to several discrete studies related to motor vehicle crash trauma. CIREN provides center participants and other researchers direct, real-life insight into mechanisms of injury resulting from motor vehicle collisions. Hypotheses regarding injury patterns and mechanisms are easily discerned from CIREN cases. These hypotheses then lead to comprehensive studies that involve NASS, occupant kinematics modeling, biomechanics laboratory testing, etc. The results of these studies are ultimately used by the automotive safety industry to make automobiles safer. Several recent UAB publications and manuscripts that initiated from UAB CIREN case studies are outlined below.

Incidence and Characteristics of Motor Vehicle Collision Related Blunt Thoracic Aortic Injury According to Age

McGwin G, Reiff DA, Rue LW. "Differences in the incidence and etiology of blunt thoracic aortic injury in motor vehicle collisions by age." In press. *Journal of Trauma*.

Introduction – Motor vehicle collision (MVC) related blunt thoracic aorta injury (BAI) is rare and highly lethal. Vascular disease as related to advancing age potentially subjects older adults to increased risk of BAI; the mechanisms associated with such injuries may be different as compared to younger adults. The goal of the present study is to test this hypothesis using population-based data. **Methods** – The 1995-1999 National Automotive Sampling System (NASS) data files were utilized. NASS is a national probability sample of passenger vehicles involved in police-reported tow-away crashes. BAI was defined according to the Abbreviated Injury Scale codes. Among those with BAI, information on occupant (age, seating position, restraint use), collision (collision type, delta-V, vehicle intrusion) and outcome characteristics were obtained and compared according to age. **Results** – The overall incidence of BAI was 6.8 per 10,000 occupants and a steady increase in the BAI rate for advancing decades of life. The proportion of occupants with BAI who die at the scene of the collision is relatively consistent across all age groups (~85%). Among those who survive to receive medical care, ultimate survival is lowest among those aged 60 and older. Near-side collisions were responsible for more BAI among older adults than other age groups (50% vs. 20.6%, $p \leq 05$). Older adults sustained BAI in collisions with lower delta-V values compared with younger persons ($p \leq 05$). **Conclusions** – Older adults have the highest rate of MVC related BAI and their injuries tend to occur in less severe collisions. Age associated atherosclerosis and calcification of the great vessels, which diminish vessel elasticity and compliance, may explain this difference. A high level of suspicion for BAI among older adults should not be reserved for high-energy collisions only.

Identifying Injuries and Motor Vehicle Collision Characteristics That Together Are Suggestive of Diaphragmatic Rupture

Reiff DA, McGwin G, Rue LW. "Risk factors for diaphragm rupture in motor vehicle collisions." Accepted for presentation at the 2002 EAST meeting.

Introduction – Diaphragmatic rupture (DR) remains a diagnostic challenge due to the lack of an accurate test demonstrating the injury. As non-operative management of solid organ injury is more frequently employed, early recognition of DR has become more complicated. Our purpose was to identify motor vehicle collision (MVC) characteristics and patient injuries, which collectively could indicate DR. **Methods** – The National Automotive Sampling

System was used to identify front seat occupants involved in MVCs from 1995-99 who sustained abdominal (Abbreviated Injury Scale (AIS) ≥ 2) and/or thoracic injuries (AIS ≥ 3). The frequency of specific injuries and MVC characteristics, alone and in combination, were compared among patients with and without a DR. Odds ratios (OR) and 95% confidence intervals (CI) were calculated to quantify the association between patient injuries, vehicle collision characteristics and DR. Sensitivity and specificity were also calculated to determine the ability of organ injury and MVC characteristics to correctly classify patients with and without DR. **Results** – Overall, among drivers and front seat passengers involved in MVCs, patients with DR had a significantly higher delta-v (ΔV) (50.3 kph vs. 36.4 kph, $p < 0.0001$) and a greater degree of occupant compartment intrusion (70.6 cm vs. 52.3 cm, $p < 0.0001$). Specific abdominal and thoracic organ injuries were associated with DR including thoracic aortic tears (OR, 4.2; 95% CI 1.8-10.1), splenic injury (OR, 5.4; 95% CI 2.5-11.8), pelvic fractures (OR, 4.0; 95% CI 2.4-6.7) and hepatic injuries (OR, 2.3; 95% CI 0.9-5.7). Combining frontal or near-side lateral occupant compartment intrusion ≥ 30 cm or (ΔV) ≥ 40 kph with specific organ injuries generated sensitivity for detecting diaphragm injury ranging from 85-88%. Patients with any of the following characteristics; splenic injury, pelvic fracture, ΔV ≥ 40 kph or occupant compartment intrusion from any direction ≥ 30 cm had a sensitivity for detecting DR of 91%. **Conclusion** – We have identified specific MVC characteristics combined with patient injuries, which together are highly suggestive of DR. For this subpopulation, additional invasive procedures including exploratory laparotomy, laparoscopy or thoracoscopy may be warranted to exclude DR.

Restraint Use and Injury Patterns Among Children Involved in Motor Vehicle Collisions

Valent F, McGwin G, Rue LW. "Restraint use and injury patterns among children aged 0 to 11." Submitted. *Journal of Trauma*.

Introduction – Motor vehicle collisions (MVC) are the leading cause of death among children over 1 year of age (YOA). Use of appropriate restraint systems is associated with reductions in morbidity and mortality in this age group. No studies have evaluated the association between specific injury patterns and restraint use among children. The purpose of this study was to evaluate differences in rates of specific injuries according to restraint use among children 0-11 YOA. **Methods** – The 1995-1999 National Automotive Sampling System (NASS) data files were utilized. NASS is a national probability sample of passenger vehicles involved in police-reported tow-away crashes. Information on occupant (seating position, restraint use), collision (change in velocity, vehicle intrusion) and outcome characteristics was evaluated. Rates for specific injuries (Abbreviated Injury Scale [AIS] ≥2) were calculated and compared according to restraint use. **Results** – Between 1995 and 1999 there were approximately 1.5 million children 0-11 YOA involved in police-reported tow-away MVCs; 36,640 experienced an injury of AIS ≥ 2 (2.4/100). Proper restraint use varied by YOA subgroups; 0-3 (53.9%), 4-7 (60.5%), 8-11 (74.7%). Injury rates were lower among properly restrained than among unrestrained children. Additionally, improperly restrained occupants had higher rates than those properly restrained, and rates of face, upper extremity, and lower extremity injury were significantly higher among improperly restrained children than among those properly restrained. **Conclusion** – Proper restraint use among children is associated with lower rates of injury. Educational initiatives should focus not only on encouraging restraint use but also ensuring that parents know the appropriate age dependent restraint method.

Splenic Injury in Side Impact Motor Vehicle Collisions – The Effect of Occupant Restraints

Reiff DA, McGwin G, Rue LW. "Splenic injury in side impact motor vehicle collisions – The effect of occupant restraints." In press. *Journal of Trauma*.

Introduction – Side impact motor vehicle collisions (MVCs) are associated with higher morbidity and mortality compared to other types of MVCs. The stiffness of the lateral aspect of the vehicle and restraint use may play a role. The purpose of this study was to evaluate the role of restraint use, vehicle size and compartment intrusion on the incidence of splenic injury in side impact MVCs. **Methods** – The National Automotive Sampling System (NASS) was used to identify drivers involved in side impact collisions for the years 1996-1998. The incidence of splenic injury in these collisions was compared according to restraint use, vehicle size and magnitude of vehicle crush. Information on the perceived etiology of splenic injuries sustained in the MVC was also obtained from NASS investigator records. **Results** – Overall, among drivers involved in side impact MVCs, restraint use was associated with a significantly reduced rate of mortality (odds ratio [OR]= 0.40, $p<0.0001$) and splenic injury (OR=0.76, $p<0.0001$). Restrained drivers of small vehicles (<2,500 lbs.), however, had a higher incidence of splenic injury in both minimal (lateral intrusion < 30 cm.) (OR=60.1, $p<0.0001$) and severe (lateral intrusion > 30 cm.) (OR=4.0, $p<0.0001$) magnitudes of vehicle crush on the driver's side of the vehicle. For both mid-sized (2,500 – 3,000 lbs.) and large (>3,000 lbs.) vehicles, restraint use was associated with a lower risk of splenic injury regardless of the magnitude of crush. In nearly all cases of splenic injury, the left vehicle interior was the source of injury. **Conclusion** – Overall, restraint use is associated with lower rates of splenic injury and mortality in side impacts. Despite this fact, restrained drivers of small vehicles have a higher risk of splenic injury following lateral impact MVCs when compared with unrestrained drivers. Evaluation of the combined role of restraint use, crash and injury patterns may provide novel insight regarding vehicle safety design features.

Gender Differences In The Incidence Of Below Knee Fractures Following Offset Frontal Motor Vehicle Collisions

McGwin G, Reiff D, George R, Davidson J, Rue LW. "Gender differences in below knee fractures following offset frontal collisions." In preparation.

Introduction – Motor vehicle collisions (MVCs) are the leading cause of injury-related deaths in the United States. While the fatality rate associated with MVCs has dramatically fallen as personal restraint use has increased, the rate of lower extremity (LE) injuries has not been significantly affected by their use. Lower extremity injuries are costly and the cause of permanent disability and impairment following MVCs. Previous authors have found females to be at particular risk of LE fractures and attributed this gender dimorphism to their shorter stature. **Methods** – The National Automotive Sampling System was used to identify drivers involved in frontal MVCs from 1995-99. The rate of below knee fractures was compared between males and females both overall and stratified by occupant and crash characteristics. Odds ratios (ORs) and 95% confidence intervals (CIs) were calculated to quantify the association between gender and below knee LE fractures. **Results** – Below knee fractures following offset frontal MVCs occur less frequently among males compared with females (OR 0.61, 95% CI 0.43-0.85). Neither age nor ΔV, the change in velocity at the time of collision, was able to explain this observed difference. Among occupants who sat with the seat in the middle or back position, males had a lower incidence of below knee fractures (OR 0.67, 95% CI 0.46-0.97); this pattern was also present among those seated in the forward position (OR 0.26, 95% CI 0.07-0.93). **Conclusion** – Females are at greater risk of below knee fracture regardless of height, seat position and ΔV following offset-frontal MVCs. Possible explanations of these findings include footwear, driving habits and/or bone density. These findings warrant further investigation by automobile and federal agencies in an effort to reduce these lifelong disabling injuries.

Injury Patterns Among Older Adults Involved in Motor Vehicle Collisions – The Role of Near Side Collisions

McGwin G, McRae WE, Taylor AJ, Davidson JS, Rue LW. "Injury patterns among older adults involved in motor vehicle collisions – The role of near side collisions." Submitted.

Background – Automobile collisions are more likely to result in injury and result in poorer outcomes for older adults. Of particular concern are side-impact collisions, which have been shown to result in elevated morbidity and mortality for older adults. The objective of this study is to compare injury patterns in near-side (NS) versus non-NS collisions among patients 60 years of age and older treated at a Level I trauma center. **Methods** – The study population was 201 patients aged 60 years and older admitted to a Level I trauma center for injuries sustained in motor vehicle collisions. Injury patterns were compared between patients involved in NS versus non-NS collisions. **Results** – Differences in injury patterns between NS and non-NS patients were a function of seatbelt use and vehicle speed. Among restrained patients and those involved in high-speed collisions, NS patients were more likely to sustain head injuries and pelvic fractures. Among unrestrained patients, tibia/fibula fractures were more common among NS compared with non-NS patients (NS: 42.9% vs. non-NS: 11.4%; p=0.07). **Conclusion** – Injury patterns among older adults involved in motor vehicle collisions differ according to characteristics of the collision. Future research should determine whether these injury patterns are independent of age.

The Association Between Body Mass Index, Restraint Use, and Fatality in Motor Vehicle Collisions

Moran SG, McGwin G, Reiff DA, Rue LW. "The association between body mass index, restraint use, and fatality in motor vehicle collisions." In press. *45th Annual Proceedings of the Association for the Advancement of Automotive Medicine, 2001.*

Background – The purpose of this study was to characterize the association between BMI, body habitus (height and weight) and risk of death for restrained drivers involved in MVCs. In characterizing any association, the authors sought to identify patterns of the rare occurrence of fatality in MVCs. **Methods** – The 1995-1999 National Automotive Sampling System Crashworthiness Data System was utilized. Fatality rates were calculated and compared between BMI and body habitus categories. The data was further stratified according to general area of damage; fatality rates were then compared. To quantify the magnitude of these associations, fatality relative odds ratios (ORs) and 95 percent confidence intervals (CIs) were calculated with the 50th percentile Hybrid III male crash dummy as the reference point, p-values of ≤ 0.05 were considered statistically significant. SUDAAN® 7.52 was used for all statistical analyses. **Results** – Body mass index as a descriptor of body habitus was not associated with fatality rates. When grouped according to height and weight as descriptors of body habitus, fatality rates for restrained drivers were significantly different in several subgroups. In MVCs overall, fatality rates were decreased in three of the lighter subgroups. The fatality rate was increased in the subgroup shorter than the Hybrid III in driver's side collisions and the lighter subgroup in frontal collisions. The 5th percentile female subgroup did not have fatality rates and ORs significantly different from the H3CD. **Conclusions** – The 50th percentile male Hybrid III Crash

Dummy plays a major role in vehicular cabin interior design and crash testing. For drivers with a dissimilar body habitus, the vehicle cabin/body fit changes and the safety features perform differently which may account for these observations.

Injury Rates Among Restrained Drivers in Motor Vehicle Collisions – The Role of Body Habitus

Moran SG, McGwin G, Metzger J, Windham ST, Reiff DA, Rue LW. "Injury rates among restrained drivers in motor vehicle collisions – The role of body habitus." In press. *Journal of Trauma*.

Background – Previous studies have examined the independent effects of occupant height, obesity, and body mass index in motor vehicle collisions and identified related injury patterns. The hypothesis of this study was that as the driver's body habitus diverges from the 50% percentile male Hybrid III Crash Dummy (H3CD), the frequency of injury changes. **Methods** – The 1995-1999 National Automotive Sampling System Crashworthiness Data System was utilized. Study entry was limited to restrained drivers who were then subdivided into height and weight categories. Incidence rates were calculated for injuries to selected body regions as defined by the Abbreviated Injury Scale for overall, frontal, and driver's side collisions. **Results** – When grouped according to height and weight as descriptors of body habitus, injury rates for restrained drivers were increased as well as decreased in several subgroups. This association was seen in overall, frontal and driver's side collisions. **Conclusions** – The H3CD plays a major role in vehicular cabin interior design and crash testing. For drivers with a dissimilar body habitus from that of the H3CD, the vehicle cabin/body fit changes and the safety features may perform differently which could account for these observations.

Common Bile Duct Transection in Blunt Abdominal Trauma: Case Report Emphasizing Mechanism of Injury and Therapeutic Management

Melton SM, McGwin G, Reiff DA, Waller H, Davidson JS, Vickers S, Rue LW, "Common bile duct transection in blunt abdominal trauma: case report emphasizing mechanism of injury and therapeutic management," submitted. *Journal of Trauma*.

Extrahepatic biliary tract injuries occur in three to five percent of all abdominal trauma victims with 85% resulting from penetrating wounds. Extrahepatic biliary tract injuries from blunt abdominal trauma involve the gallbladder alone in 85% of the cases. Therefore, common bile duct injuries from blunt abdominal trauma are exceeding rare, especially those resulting in complete transection of the duct. A case of blunt abdominal trauma following a motor vehicle crash resulting in complete transection of the common bile duct will be presented with a review of diagnostic techniques. The management of such injuries will be delineated and details of the mechanism of injury in this motor vehicle crash will be closely examined using data obtained from an in-depth crash investigation and analysis.

Summary

The Mercedes-Benz CIREN Center at UAB focuses on the evaluation of pelvic fractures, head injuries, and injuries sustained by elderly crash victims and collaborates with faculty from UAB's School of Engineering, Public Health and Medicine. CIREN analyses have served as the intellectual spark for multiple population-based studies to help better understand and improve the translation from automotive design and crash testing to real world MVCs and the associated fatality/injury. Questions that arose from these analyses have also lead to involving The Children's Hospital and Coroner's Office as major contributors and collaborators in the CIREN review process. Future plans include expanding outreach by taking our findings to pre-hospital entities in an effort to raise acuity level and improve patient care. Additionally, our surgeons and researchers will be involving the expertise of Mercedes-Benz safety and test engineers in the early phases of injury analysis research to bring together the science of vehicle design and testing with what occurs in the real world environment.

Ford Inova Fairfax Hospital CIREN Center

CIREN Program Report

The Inova Regional Trauma Center (IRTC) is one of the busiest trauma centers in the Washington, DC, metropolitan area. In 2000, the trauma center treated more than 2,300 severely injured patients with the majority of patients injured in motor vehicle crashes. Our attending staff of four full-time trauma surgeons receives assistance from a group of community-based general surgeons.

The IRTC is committed to decreasing trauma-related death and disability through education, outreach, prevention, and research to improve the quality of life for everyone in the community. Seventy-eight percent of the patients treated at the IRTC are from Fairfax County, which is an affluent community with a high percentage of new vehicles in the population resulting in a higher probability of encountering new vehicle safety technology. Some of our recent highlights include:

- The IRTC experienced very substantial growth in patient volume over the past decade. We witnessed an increase of 14% in the year 2000, consistent with a nearly three-fold increase in patient volume since the late 1980's.
- Over the past 18 months, we acquired over $1.5 million in grants and charitable gifts to support our core missions of patient care, education/outreach, injury prevention and research.
- Since 1999, we have published 23 articles in peer reviewed medical journals and 16 book chapters. During the same time interval, our group had 21 national research presentations.
- We received a $180,000 grant from the motor vehicle administrations of Maryland, Virginia and the District of Columbia for research on aggressive driving in the Washington metropolitan area, as part of the Smooth Operator Campaign.
- Our Reality Check program, established in 1999 to support young driver safety and education, continued with funding from the DMV in Virginia. This program targets the 10,000 students who enroll in driver's education in Fairfax County each year in an effort to reduce teenagers driving under the influence (DUI). It is a collaborative effort with the Fairfax County schools and incorporates an attitude survey to measure program outcomes. This program also receives support from the Bank of America Foundation and private donors.
- We received funding from CDC for our patient support program, REBUILD. REBUILD is a program that focuses on the psychosocial concerns of the trauma patient. The program also receives funds from the Bank of America Foundation as well as private donors.
- We initiated the "Kids Can't Fly" program to educate parents and caregivers about the risks of children falling from open windows.
- We were selected by the Brain Trauma Foundation (BTF) to be a regional center of excellence. The IRTC received grant support to implement the BTF Guidelines for the Pre Hospital Management of Traumatic Brain Injury and to educate EMS agencies through a "train the trainer" program in partnership with the Fairfax County Fire and Rescue Department.
- We partnered with the Fairfax County Police in sponsoring a Mountain Bike Competition for law enforcement officers from police agencies across the Mid-Eastern region of the US. The proceeds will support prevention efforts in traumatic head injury in children.
- We concluded the first year of implementation of the Substance Abuse Focused Education (S.A.F.E.) program in partnership with the Fairfax County Juvenile Court system and the county's Alcohol Safety Action Program (ASAP). This is a court-mandated program offered to juveniles charged with an alcohol or substance abuse offense. As part of the program, the teenager, accompanied by a counselor, visits patients on different hospital units at the IRTC, attends a Medical Examiner lecture, and composes an essay on the experience. To date over 300 youths have participated in this program.

- We received the "Best Practice" award at the 5th annual conference of Bishop + Associates for the Northern Virginia Injury Prevention Center's website and prevention efforts. Bishop + Associates are a national consulting firm specializing in trauma care.
- We continued our very successful trauma externship program. This program enabled pre-professional students from throughout the country, who have an interest in a career related to trauma, to shadow caregivers across the continuum of care and observe the components of the trauma system.

In May 2000, Ford Motor Company awarded a $1 million grant to the IRTC to establish the 9th Crash Injury Research & Engineering Network Center. The trauma center's unique relationship with the Fairfax County Fire and Rescue Department as well as the Fairfax County Police Accident Reconstruction Unit played a vital role in establishing the CIREN Team at the IRTC. To complete the team, the IRTC has contracted engineering consulting services from the Automobile Safety Laboratory in the Department of Mechanical and Aerospace Engineering at the University of Virginia.

The CIREN Center at the IRTC has the unique opportunity to capture crash events and information because of our long standing integration with the Fairfax County Fire and Rescue Department and the on-scene real-time availability of the Fairfax County Police Accident Reconstruction Unit for most of our cases. The Fairfax County Fire and Rescue Department provide all-professional staffing for vehicle crash victims backed up by the Inova Fairfax Hospital Helicopter service (Inova Medical AirCare). The Fairfax County Fire and Rescue Department have an average response time to crashes of 4–5 minutes. The helicopters are less than 10 minutes from any point in the county. The Fairfax County Police Department has a specialized Accident Reconstruction Unit (ARU) available on call 24 hours per day, 7 days a week in response to fatal and other severe crashes (including potential CIREN cases). This provides real time, accurate reconstruction of crashes and more reliable data.

All parties actively participate in the monthly case reviews. Pre-hospital personnel responding to the scene and attending physicians are invited to share their observations and expertise during the case reviews providing additional insight into the cases discussed.

Fairfax County Fire and Rescue

Pre-hospital providers are an important part of the trauma system. Without properly trained personnel, skilled extrication, rapid assessment of the patient, and rapid transport to an appropriate facility would not be possible. For these reasons, the Fairfax County Fire & Rescue Department has also become an integral part of our CIREN team. Information from the first unit at the scene is vital to paint a complete picture of the crash scene. In-services were held for pre-hospital providers and digital cameras were distributed to each station captain to enable the responding units to take photos at the scene and extrication process where possible. In turn, Fairfax County Fire & Rescue has held an in-service for the other members of the CIREN team to teach researchers how to differentiate impact crash damage from extrication related vehicle alterations and to better comprehend the roles, responsibilities, and capabilities of heavy rescue companies. Once a patient has agreed to participate in the CIREN program, Captain Christine Woodard, our Fire and Rescue Liaison is contacted to interview pre-hospital personnel that first arrived at the scene. The information gathered includes measures taken during extrication, extrication equipment used, alterations made to the vehicle during the extrication, and in what position and condition the patient was found. Pre-hospital providers are invited and encouraged to participate in the monthly case reviews and feedback is provided to personnel that were unable to attend. Fairfax County Fire & Rescue has been active in participating in the Quarterly CIREN Meetings held by NHTSA and in giving presentations related to their role in the field. In the coming months the CIREN program has planned to further integrate pre-hospital providers by scheduling Grand Rounds at Fire Stations. The goal is to educate pre-hospital providers to characteristic injury patterns that occur in crashes.

Fairfax County Police – Accident Reconstruction Unit

The Fairfax County Police Department's Accident Reconstruction Unit (ARU) is an important participant in the CIREN program. The Ford Inova Fairfax Hospital CIREN Center obtained the support of the Fairfax County Board of Supervisors to utilize the expertise of the ARU for this project. The team itself is a leader in accident reconstruction, having been one of the first units of its kind, and is recognized internationally for its accomplishments. The ARU conducts real time scene investigation for all fatal crashes and crashes in which the occupant is perceived to have suffered life threatening injuries in Fairfax County. They respond to the scene before the vehicles are moved and are able to obtain photographs of the vehicles and evidence at final rest; obtain and record measurements of evidence; and establish the speed, Delta V, maximum crush, and relevant contact points that help determine injury sources. Training conducted by the ARU for local, state and federal agencies explains the CIREN program and involvement by the police. The members of the team attend numerous civic meetings throughout Fairfax County where the CIREN program is discussed. The Ford Inova Fairfax Hospital CIREN Center is currently the only CIREN Center that utilizes law enforcement personnel as the crash investigators. This allows for a greater involvement of the police, fire and rescue and the local community, and broadens the reach of the CIREN Center into the community. The ARU team includes:

- Detective James D. Bean, Fairfax County Police Accident Reconstruction Unit
- Detective James J. Banachoski, Fairfax County Police Accident Reconstruction Unit
- Detective Elizabeth Dohm, Fairfax County Police Accident Reconstruction Unit

Inova Regional Trauma Center

As an ACS Level I verified trauma center, the IRTC is committed to providing excellence and quality in care to all patients. CIREN allows clinicians, crash reconstruction experts and engineers to collaborate in the in-depth analysis of vehicle crashes and patient injuries with the ultimate goal of improving auto safety and decreasing death and disability. The information CIREN offers is being utilized to increase the diagnostic sensitivity and specificity of the trauma examination by the identification of patterns of contact in particular types of motor vehicle crashes that are predictive of specific injuries. Although Inova Fairfax Hospital has just recently joined CIREN, the already existing relationship with the Fairfax County Fire & Rescue Department and the Fairfax County Police Department, has allowed this CIREN Center to "go live" in a very short time. The close relationship between the Fire & Rescue Department and Police Department facilitates excellent communication and cooperation. The IRTC has worked closely with the Fairfax County Fire and Rescue Department and the Fairfax County Police Department on many research and injury prevention projects.

Ford Inova Fairfax Hospital CIREN Team

- Samir M. Fakhry, MD, FACS, principal investigator
- Dorraine D. Watts, PhD, RN, principal investigator
- Christine Burke, study coordinator
- Colleen Gilmore, research associate
- Eileen Caulfield, research analyst
- Sharon Plater, research associate

Dr. Fakhry demonstrates MAST pants during a case review.

The Ford Inova Fairfax Hospital CIREN Center went "live" in November 2000. As of August 31, 2001 the CIREN team has screened 1,248 patients and has enrolled forty-six patients into the CIREN study. Detailed case analysis including pre-hospital, scene, hospital data and engineering are presented and discussed at monthly multi-disciplinary case reviews, which are also attended by representatives from the Ford Motor Company via video conferencing.

Below are 7 selected CIREN related presentations and outreach

May 2000 – the Ford Inova Fairfax Hospital CIREN Center held an opening ceremony that was attended by community leaders and the Secretary of Transportation Rodney Slater. The Fairfax County Fire and Rescue Department presented a crash victim extrication demonstration.

September 2000 – the CIREN team (principal investigators, study coordinator, research associate and a representative from the ARU) traveled to Boston to attend a four-day training session related to CIREN and NASS database management, quality control, NASS coding and report writing.

October 2000 – the Ford Inova Fairfax Hospital CIREN Team and the IRTC sponsored a Child Safety and Booster Seat event as part of Child Health Month. The event brought together child seat technicians from the Fairfax County Police Department, Fairfax County Fire & Rescue and Fairfax Safe Kids Coalition to help install and ensure the proper use of child safety seats, as well as set up educational booths and display boards for the community.

November 2000 – Ford Motor Company was an invited speaker at the IRTC's Annual Trauma Symposium. Ford Motor Company presented **Innovation in Automotive Occupant Safety**.

Samir M. Fakhry, MD, FACS, chief, trauma services and principal investigator, Ford Inova Fairfax Hospital CIREN Center held an educational presentation at the Surgery Grand Rounds and Residents Meeting.

June 2001- Dorraine Watts, PhD, principal investigator and Detective James Banachoski attended and completed the NASS training held by the Transportation Safety Institute.

Samir M. Fakhry, MD, FACS, chief, trauma services, principal investigator, CIREN and Dorraine D. Watts, PhD, RN, trauma research manager, principal investigator, CIREN have held educational presentation at individual Fairfax County Fire & Rescue Stations. Educational topics included liver injuries associated with shoulder belt only use and the CIREN program.

Below are 7 selected recent motor vehicle-related articles

Watts, D., Fakhry, S., Pasquale, M., Kurek, S., Malhotra, A., Fabian, T., & Boulanger, B. (2002). Motor Vehicle Crash (MVC) And Abdominal Seatbelt Mark As Risk Factors For Perforating Small Bowel Injury (SBI): Results From A Large Multi-Institutional Study. *Proceedings of the Eastern Association for the Surgery of Trauma Fifteenth Scientific Assembly, January 2002, Orlando, FL.*

Watts, D., Hauda, W., & Anderson, J. (2001). The Role of Airbags in Eye Injures: Protective or Injury Producing? *Proceedings of the American College of Emergency Physicians 2001 Research Forum, October 2001, Chicago, IL.*

Watts, D. (2001). Management of Patients with Neurologic Trauma. S. Smeltzer, & B. Bare (editors), *Medical Surgical Nursing* (10th ed., Vol. (in press) Chapter 58). Philadelphia: Lippincott.

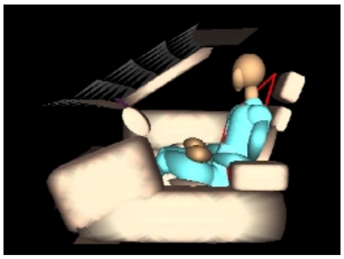
Rivera, L., Peitzman, A. B., ..., Fakhry, S., & et.al. (2001). Contributions of Age and Gender to Outcomes of Blunt Splenic Injury in Adults: Multicenter Study of the Eastern Association for the Surgery of Trauma. in *Proceedings of the Fourteenth Annual Scientific Assembly of the Eastern Association for the Surgery of Trauma* (p. page 46).

Peitzman, A. B., Harbrecht, B. G., ..., Fakhry, S., & et.al. (2001). EAST Study of Failure of Observation of Blunt Splenic Injury in Adults. *Journal of Trauma.*

Hanfling, D., Watts, D., Mayer, T., Trask, A., & Fakhry, S. (2001). Forming the Initial Link: Educating Providers in the Guidelines for Pre-hospital Management of Traumatic Brain Injury. *Proceedings of the American College of Emergency Physicians 2001 Research Forum, October 2001, Chicago, IL.*

Fakhry, S., & Salaita, K. (2001). Aggressive Driving: Preliminary Analysis of a Serious Threat to Motorists in a Large Metropolitan Area. in *Proceedings of the Fourteenth Annual Scientific Assembly of the Eastern Association for the Surgery of Trauma* (page 122).

Engineering by the University of Virginia



The Automobile Safety Laboratory is an interdisciplinary program of the School of Engineering and Applied Science and the School of Medicine, through the Center for Prevention of Disease and Injury of the University of Virginia (UVA). This facility is one of a limited number of laboratories conducting impact biomechanics research with both dummies and cadavers. The laboratory is a 10,000 sq. ft. facility equipped with a wide range of biomechanical test equipment, a machine shop, dummy laboratory, and surrogate storage.

In its role with CIREN, the UVA Automobile Safety Laboratory forms the link between the vehicle dynamics (crash reconstructionists) and the occupant injury information (doctors, nurses, EMTs) to determine injury causation.

Occupant kinematics – Personnel at the ASL have years of experience in conducting sled tests with both cadavers and dummies to understand how crash dynamics relate to occupant kinematics. Ultimately injuries occur when the body interacts with the vehicle interior, and understanding occupant kinematics is crucial to this interaction.

Injury mechanics – The ASL conducts sled tests with whole cadavers to produce and study injuries. Whole cadavers have also been used in isolated out-of-position airbag tests to study the injuries caused in these situations. Component tests of specific body segments (e.g., lower extremities) have been performed for injury criteria development.

Modeling – Advanced computer models (both multi-body and finite element) have been used to study both occupant kinematics and injury mechanics. Multi-body models allow parametric studies to explore the effects of occupant position, size, etc. on occupant kinematics. Finite element models representing bones, ligaments, tendons can explore how external loads cause high stresses and injuries on specific body components.

Personnel – Individuals at the ASL not only have experience in current ASL biomechanical research activities, but come from other organizations in the automotive safety world, bringing valuable experience in crash reconstruction, vehicle testing, etc.

Education – Prior to the official CIREN case reviews, the ASL has its own internal case review meetings discussing each case in detail. These reviews are attended by professors, research staff, graduate students, doctors, and other auto safety engineers. This collaboration of people with expertise in multiple areas is crucial to determining the most logical explanations for injury causation. These meetings are an especially excellent method for teaching students how injuries occur in the real world crash environment. Knowledge gained from the work in CIREN will also be incorporated into a School of Engineering & Applied Science graduate course on Injury Biomechanics.

Effect on research and testing – Our experience and knowledge on injury causation are always being improved with more cases and more data. The detailed data from CIREN cases allows us to see patterns of injuries that may lead to new research ideas and provide information on how to realistically design testing environments. Even when testing with cadavers (as opposed to dummies) there are injuries that cannot be reproduced due to post-mortem physiological changes. The CIREN data allows us to study in-depth information on injuries, which can be incorporated into our future research.

Froedtert Hospital–Medical College of Wisconsin CIREN Center

CIREN Program Report

**Directors: Thomas A. Gennarelli, MD,
Dennis J. Maiman, MD, PhD**

This Center is sponsored by the administration of the Medical College of Wisconsin (MCW) and its Department of Neurosurgery and Froedtert Hospital, a principal adult teaching hospital of the College. The Department directs

nationally recognized comprehensive head and spinal cord injury care centers with long-term follow-up care. The Department includes clinicians, biomedical engineers, and research scientists with strong reputations in impact biomechanics. Facilities include the Neuroscience Laboratories, established in 1964 and incorporating over 25,000 square feet of research space. Research functions range from studies of neurotrauma on a cellular level to full-scale vehicular crashworthiness capabilities. While head and spine trauma is a specialty, this laboratory has been assisting NHTSA in various aspects of biomechanical research. Since 1988 the Laboratory has been supported by the Center for Disease Control and since 1978 by the Department of Veterans Affairs.

Frontal impact, side impact, rear impact, and pediatric trauma research have been in progress for studying human tolerance, mechanisms of injury, and evaluation of anthropomorphic test devices.

Froedtert Hospital and the Children's Hospital of Wisconsin are Level One trauma centers located on the MCW campus. The catchment area is approximately 2,000,000 people. The Flight for Life program includes helicopters in Milwaukee and northern Illinois and serves a 200-mile radius. This unique integration of engineers, scientists, and clinicians all committed to the study of neurotrauma, in a facility incorporating two major trauma centers and a long history of injury research, makes the Medical College of Wisconsin an ideal site for CIREN activities.

Objectives

- Investigate real-world crashes to:
- Reconstruct and understand crash and injury causation
- Improve prognosis and treatment for accident trauma patients
- Follow-up of treatment regimen
- Reduce recovery time and treatment costs
- Simulate crash scenarios in laboratory environment
- Disseminate data to industry, regulatory and public agencies
- Develop strategies to reduce fatalities and injuries in automobile accidents
- Provide information to improve public infrastructure to reduce accidents
- Develop and disseminate safety messages to the public
- Train health care providers in vehicular safety and associated care

Unique Focus:

- This CIREN Center will be the first to focus its activities on brain and spinal cord injuries in the vehicular environment, and
- On vehicular injuries to the entire age spectrum especially to the very young and the elderly, and
- On assuring quality improvement measures for injury scaling and crash investigation

Mission

Mission of the CIREN Center with the Medical College of Wisconsin (MCW) is to:

- Teach and train doctors and scientists of tomorrow while enhancing the skills of today's health professionals.
- Create new knowledge in basic and clinical science through biomedical and health services research
- Provide patient care humanely and expertly
- Provide leadership in health services
- Forge local, regional, national, and global partnerships in education, health care, and research for the betterment of human health
- Be a national repository for impact biomechanics and biomedical research

The MCW and Froedtert Hospital system is the oldest trauma care system and one of the two adult Level I trauma centers in Wisconsin. It serves a population of approximately two million. The catchment area includes the eastern half of the Upper Peninsula, northern Illinois, especially Lake and northern Cook counties, and neighboring Racine, Kenosha, Waukesha, Washington, and Ozaukee counties. Milwaukee County alone is approximately 240 square miles. The Flight for Life helicopter serves approximately 200-mile radius. Over 850 full-time faculty and professionals (MD and PhD) have appointments at MCW.

Proven partnerships and collaboration exists between treating physicians, other health care providers, emergency personnel, and biomedical researchers. MCW is fully committed to biomedical research and training.

CIREN Center at MCW derives its uniqueness and strength from a) internationally renowned surgeons and researchers at the trauma center, b) world-class biomechanics and engineering investigators, and c) the unparalleled impact testing facilities. The close collaboration between these groups, housed on a single campus, allows seamless operation and provides the environment to achieve the Center's objectives and further its mission.

Clinical Facilities

Both an adult-care hospital and a pediatric-care hospital (Children's Hospital of Wisconsin, CHW) are located on the MCW campus. These hospitals house the comprehensive trauma centers with a common Emergency Room (ER) facility. Two helicopters (Flight for Life) support the emergency needs. The trauma team has an excellent relationship with the Milwaukee County Medical Examiner, Emergency Medical Services (EMS), and the Milwaukee Police Department. The Clinical faculty at MCW, with the unique ability to access out-of-hospital databases, directs the out-of-hospital care and is closely involved with the ER.

MCW is the largest provider of EMS in the State of Wisconsin. The EMS system has a computerized database of all patient care records for individuals transported by the Milwaukee County paramedics units. The Traffic Incident Management Enhancement program (developed in-house) includes video ramp metering and video monitoring of local major highways. This real-time information is provided to the Sheriff and the hospital. The medical director of EMS is a faculty member of the Department of Emergency Medicine and a pediatric specialist at MCW. As a trauma center, the SICU, ICU, and NICU are well established with full facilities. Follow-up care is possible with capabilities for prospective data collection.

Collaboration

CIREN Center is a collective effort of several nationally recognized MCW departments and their faculty.

The Department of Neurosurgery directs comprehensive head and spinal cord injury care centers. The department's faculty is internationally reputed in neurotrauma and in impact biomechanics. Proven and ongoing research collaboration exists with faculty from other departments including Emergency Medicine, Neurology, Orthopaedic Surgery, Physical Medicine and Rehabilitation, Radiology, and Surgery, Trauma and Critical Care.

The Department of Emergency Medicine is a leader in out-of-hospital care and provides core leadership in the initial evaluation of trauma patients. Research programs include trauma registry development for public policy implications on intentional injuries and international travel safety.

The Department of Physical Medicine and Rehabilitation provides comprehensive follow-up care for trauma patients from consultation in the trauma ICU to community re-entry for all age groups.

The Department of Radiology has unique access to media such as teleradiology and advanced imaging devices such as CT and MR scanners. Through a strong relationship with GE Medical Systems, the department has access to the most advanced imaging systems including world-renowned testing facilities at GE.

The Department of Orthopaedic Surgery has significant interest in trauma cases, and clinicians from this group are well known in the community for patient care.

The Department of Surgery, Trauma and Critical Care forms the principal core for outcome studies. Investigation in this area is intensely pursued by trauma physicians in adult and pediatric hospitals. Nationally recognized clinical and biomedical investigators lead the respective teams. Community outreach activities are also a part of the agenda.

Applied research in areas of impact biomechanics and outcomes are an integral part of our mission. The faculty is fully committed to gather, analyze, and disseminate information to the scientific community and public. Present accomplishments include authoring books on motor vehicle-related head and neck injuries; contributing chapters on numerous injury-related issues; peer-reviewed journal articles; presentations at conferences such as Stapp, IRCOBI, and AAAM; active participation in committees such as Injury Scaling, Stapp Association, AAAM, IRCOBI, NIH, CDC, NIDRR, and DOE; working closely with regulatory bodies such as US DOT NHTSA; acting as faculty at national and international courses such as those organized by SAE professional development seminars and TOPTEC, AAAM; serving as members of advisory committees of local and national Injury Centers; providing periodic annual technical briefs to agencies such as NHTSA; informing the public through media such as newspapers and television interviews; and acting as consultants to private organizations.

Key Personnel Fact Sheet

Co-Directors

Thomas A. Gennarelli, MD

Professor and Chair Department of Neurosurgery

Current Injury Activities and Leadership Positions:

- International Neurotrauma Society: President
- International Research Council on the Biomechanics of Impact (IRCOBI): Board of Directors
- World Federation of Neurosurgical Societies: Neurotraumatology Committee
- Association for the Advancement of Automotive Medicine: Board of Directors
- International Injury Scaling Committee: Co-Chair
- American Brain Injury Consortium: Executive Committee
- Coalition for American Trauma Care: Board of Directors 1993-
- American Association for the Surgery of Trauma: Organ Injury Scaling Committee

Past Positions:

- American Association of Neurological Surgeons and Congress of Neurological Surgeons: Joint Section on Neurotrauma and Critical Care; Chairman 1988-1990
- American Association for the Surgery of Trauma: Board of Managers (Directors) 1986-1988
- Association for the Advancement of Automotive Medicine: President 1992
- Eastern Association for the Surgery of Trauma: Founding Member; Board of Directors 1987-1990
- Stapp Car Crash Conference: Board of Directors 1990-1999
- The National Neurotrauma Society: Councilor (Board of Directors) 1993-1997
- American College of Surgeons: Committee on Trauma 1983-1993
- American College of Surgeons: Advanced Trauma Life Support (ATLS) Committee; National ATLS Faculty 1987-90

Dennis J. Maiman, MD, PhD

Professor of Neurosurgery

- Director: Spinal Cord Injury Center, Froedtert Hospital
- North America Spine Society:
  - Resident-Fellow Education Committee
  - Award Committee
  - Research Planning Committee
- Director: Spine Care, Department of Neurosurgery
- Director: Spine Fellowship, Department of Neurosurgery

- American Paraplegia Society
- American Society for Biomechanics
- American Spinal Injury Association: Task Force on State SCI Incidence Reporting
- Cervical Spine Research Society: Nominating Committee
- AANS Professional Development Committee

Key Personnel:

Department of Neurosurgery

Narayan Yoganandan, PhD
Professor of Neurosurgery and Bioengineering
Chair: Biomedical Engineering
Fellow: Association for the Advancement of Automotive Medicine

Frank A. Pintar, Ph.D.
Professor of Neurosurgery and Bioengineering
Director: Neuroscience Research Laboratories
Board of Directors: Stapp Car Crash Conference

Elaine Petrucelli Wodzin, PhB
Adjunct Instructor in Neurosurgery
Former Executive Director: Association for the Advancement of Automotive Medicine
Co-Chair: International Injury Scaling Committee

Murray MacKay, DSc
Adjunct Professor of Neurosurgery
President: International Research Council on the Biomechanics of Impact (IRCOBI)
Co-Chair Program Committee and former President: Association for the Advancement of Automotive Medicine

Irma G. Fiedler, PhD
Associate Professor of Physical Medicine and Rehabilitation
Adjunct Professor of Neurosurgery

Department of Surgery

John Weigelt, MD, DVM
Professor of Surgery
Trauma Director: Froedtert Hospital
Former Chair: American College of Surgeons Committee on Trauma

Keith T. Oldham, MD
Professor of Surgery
Chief of Pediatric Surgery: Children's Hospital of Wisconsin

Andrea Winthrop, MD
Assistant Professor of Surgery
Trauma Director: Children's Hospital of Wisconsin

Karen J Brasel, MD
Assistant Professor of Surgery
Associate Trauma Director: Froedtert Hospital

Other Departments

Stephen Hargarten, MD, MPH
Professor of Emergency Medicine
Chair: Department of Emergency Medicine
Director: Injury Research Center

Jeffery Jentzen, MD
Professor of Pathology
Milwaukee County Medical Examiner

Richard Marks, MD
Assistant Professor Orthopaedic Surgery

Neil Mandel, PhD
Professor of Medicine
Associate Chief of Staff for Research: VAMCH

Facilities

Neuroscience Research Laboratories (25,000 sq feet)

The neuroscience laboratories are directed by Frank A. Pintar, PhD. They are equipped and staffed for a full spectrum of clinical and basic science investigations. Facilities include:

Biomechanics Laboratory
Neurophysiology Laboratory
Neurohistology Laboratory
Computer Analysis Facility
Machine and Electronics Shop

Medical College of Wisconsin

US Department of Transportation, NHTSA Cooperative Agreement

Directed by professors Narayan Yoganandan, PhD and Frank A. Pintar, PhD

The Department of Neurosurgery of the Medical College of Wisconsin has had a cooperative agreement with the US DOT, NHTSA, since September 1989. The work centers on biomechanical testing of human surrogates and is conducted at the Neuroscience and Biomechanics Research Laboratories housed at the Zablocki VA Medical Center in Milwaukee, Wisconsin. In general, the goals of the research are to provide data on the mechanisms and tolerance of the human body to injury in a vehicular crash. The federal government directly uses this data in establishing and upgrading federal motor vehicle safety standards. There is also a direct benefit to the constant improvement and redesign of the complete family of crash test dummies. This cooperative agreement has been renewed until 2002.

Major Accomplishments

- A series of simulated frontal impact tests were done with a new device called the "chestband" to assess chest injury criteria. The results of these studies were directly used in the recent proposal to upgrade the FMVSS 208.
- A series of tests were done to assess chest and pelvic injury in a side impact crash. This series also used the chestband to recommend new injury criteria for side impact protection and investigate possibilities of harmonization with international standards.
- A series of tests were completed providing data on the tolerance of the human forearm and specifically the smaller sized occupant to bending injuries. This data can be used in the design of safer airbags when the driver has their arm over the airbag module just prior to a crash.
- A series of tests were done to quantify neck compression injuries. Results provide direct data as to the tolerance of the human neck with respect to age, gender, and rate of load application. This data can be used for development of standards for protection in vehicle crashes.
- Investigations were completed to define the tolerance of the human foot and ankle under vehicle crash conditions. This data established initial injury criteria for use in development of improved crash test dummy foot and future safety standards.
- A series of rear impact tests were completed to assess improvements in the vehicle headrest standards.
- A series of tests to assess the potential harm of side airbags to child and small female occupants is being conducted. Preliminary information has been used to inform consumers of the potential dangers associated with occupants positioned too close to a side airbag.
- A series of tests is being conducted to provide data to improve the redesign of airbags to reduce the potential for severe neck injury to children and small female occupants.
- Many articles have been published covering the above topics in more detail. To further disseminate the above research information, numerous presentations have been given to the government and at technical conferences throughout the world.

The following is a limited list of recent injury-related publications.

Gennarelli TA. "Brain Injury, Shock and Ischemia: Theoretical Interactions." *Shock*, 8:2,1997.

Alavi A, Mirot A, et al. "Fluorine-18-FDG Evaluation of Crossed Cerebellar Diaschisis in Head Injury." *J Nucl Med*, 38(11):1717-20,1997.

Gennarelli TA, Thibault LE, Graham DI "Diffuse Axonal Injury: An Important Form of Traumatic Brain Injury." *The Neuroscientist*, 4:202-215, 1998.

Smith DH, Cecil KM, et al. "Magnetic Resonance Spectroscopy of Diffuse Brain Trauma in the Pig." *J Neurotrauma*, 15(9):665-74, 1998.

Gennarelli TA, Graham DI. "Neuropathology of Head Injury." *Seminars in Clinical Neuropsychiatry*, 3:1-17, 1998.

Gennarelli TA, Graham DI. "Neuropathology of the Head Injuries." *Semin Clin Neuropsychiatry*, 3(3):160-175, 1998.

Kimura H, Meaney DF, et al. "Magnetization Transfer Imaging of Diffuse Axonal Injury Following Experimental Brain Injury in the Pig: Characterization by Magnetization Transfer Ratio with Histopathologic Correlation." *J Computer Assisted Tomography*, 20(4):540-6, 1996.

Gennarelli TA. "The Pathobiology of Traumatic Brain Injury." *The Neuroscientist*, 3(1):73-81, 1997.

Smith DH, Chen XH, Xu BN, McIntosh TK, Gennarelli TA, Meaney DF. "Characterization of Diffuse Axonal Pathology and Selective Hippocampal Damage following Inertial Brain Trauma in the Pig." *J Neuropathology and Experimental Neurology*, 56(7):822-834, 1997.

Gennarelli TA, "The Spectrum of Traumatic Axonal Injury." *Neuropathology and Applied Neurobiology*, 22:509-513, 1996

Maxwell WL, McCreath BJ, Gennarelli, TA, et al. "Cytochemical Evidence for Redistribution of Membrane Pump Calcium-ATPase and ecto-Ca-ATPase activity, and Calcium Influx in Myelinated Nerve Fibres of the Optic Nerve After Stretch Injury." *J Neurocytol*, 24(12):925-42, 1995.

Smith DH, Meaney DF, Gennarelli TA, et al. "New Magnetic Resonance Imaging Techniques for the Evaluation of Traumatic Brain Injury." *J Neurotrauma*, 12(4):573-7, 1995.

Meaney DF, Smith DH, Gennarelli TA, et al. "Biomechanical Analysis of Experimental Diffuse Axonal Injury." *J Neurotrauma*, 12(4):689-94, 1995.

McKenzie KJ, McLellan DR, Gentleman SM, Maxwell WL, Gennarelli TA, Graham DI. "Is B-APP a Marker of Axonal Damage in Short Surviving Head Injury?" *Acta Neuropath*, 92:608-613, 1996.

Gennarelli TA. "Types and Amount of Axonal Injury in Traumatic Brain Injury." *Neuropath and Applied Neurobiology*, 22(1):44, 1996.

McIntosh TK, Smith DH, Meaney DF, Kotapka MJ, Gennarelli TA, Graham DI. "Neuropathological Sequelae of Traumatic Brain Injury: Relationship to Neurochemical and Biomechanical Mechanisms." *Laboratory Investigation*, 74(2):315-342, 1996.

Hirohiko K, Meaney DF, McGowan JC, Grossman RI, Lenkinski RE, Ross DT, McIntosh TK, Gennarelli TA, Smith DH. "Magnetization Transfer Imaging of Diffuse Axonal Injury Following Experimental Brain Injury in the Pig: Characterization by Magnetization Transfer Ratio with Histopathologic Correlation." *J Computer Assisted Tomography*, 20(4):540-546, 1996.

Bogduk N, Yoganandan N. "Biomechanics of the cervical spine Part 3: minor injuries." *Clin Biomech*, 16(4):267-275, 2001.

Cusick, JF, Pintar, FA, Yoganandan, N. (2001). Whiplash syndrome: Kinematic factors influencing pain patterns. Spine 26(11):1252-1258, 2001.

Kumaresan S, Pintar FA, Yoganandan N. "Finite element modeling of pre-tension in spinal ligaments." *J Mathematical Modeling and Scientific Computing*, 13(1-2):115-119.

Kumaresan S, Yoganandan N, Pintar FA. "Pediatric neck injury scale factors and tolerance." *Biomed Sci Instrumentation*, 37:435-440, 2001.

Pintar FA, Kumaresan S, Yoganandan N. "Geometrical idealization of uncovertebral joints of the cervical spine." *J Mathematical Modeling and Scientific Computing*, 13(1-2):133-135, 2001.

Pintar FA, Kumaresan S, Yoganandan N, Yang A, Stemper B, Gennarelli, TA. "Biomechanical modeling of penetrating traumatic head injuries: A finite element approach." *Biomed Sci Instrumentation*, 37: 429-433, 2001.

Stemper BD, Yoganandan N, Pintar FA, Sun Z. "Development of extension kinematic corridors to validate a head/neck finite element model." *Biomed Sci Instrumentation*, 37:239-244, 2001.

Thacker BH, Nicolella DP, Kumaresan S, Yoganandan N, Pintar FA. "Probabilistic finite element analysis of cervical spine." *J Mathematical Modelling and Scientific Computing*, 13(1-2):12-21, 2001.

Wijman CA, McBee NA, Keyl PM, Varelas PN, Williams MA, Hanley DF, Wityk RJ, Razumovsky AY. "Diagnostic impact of early Transcranial Doppler Ultrasonography on TOAST classification subtype in acute cerebral ischemia." *J Cerebrovascular Disease*, 11:317-323, 2001.

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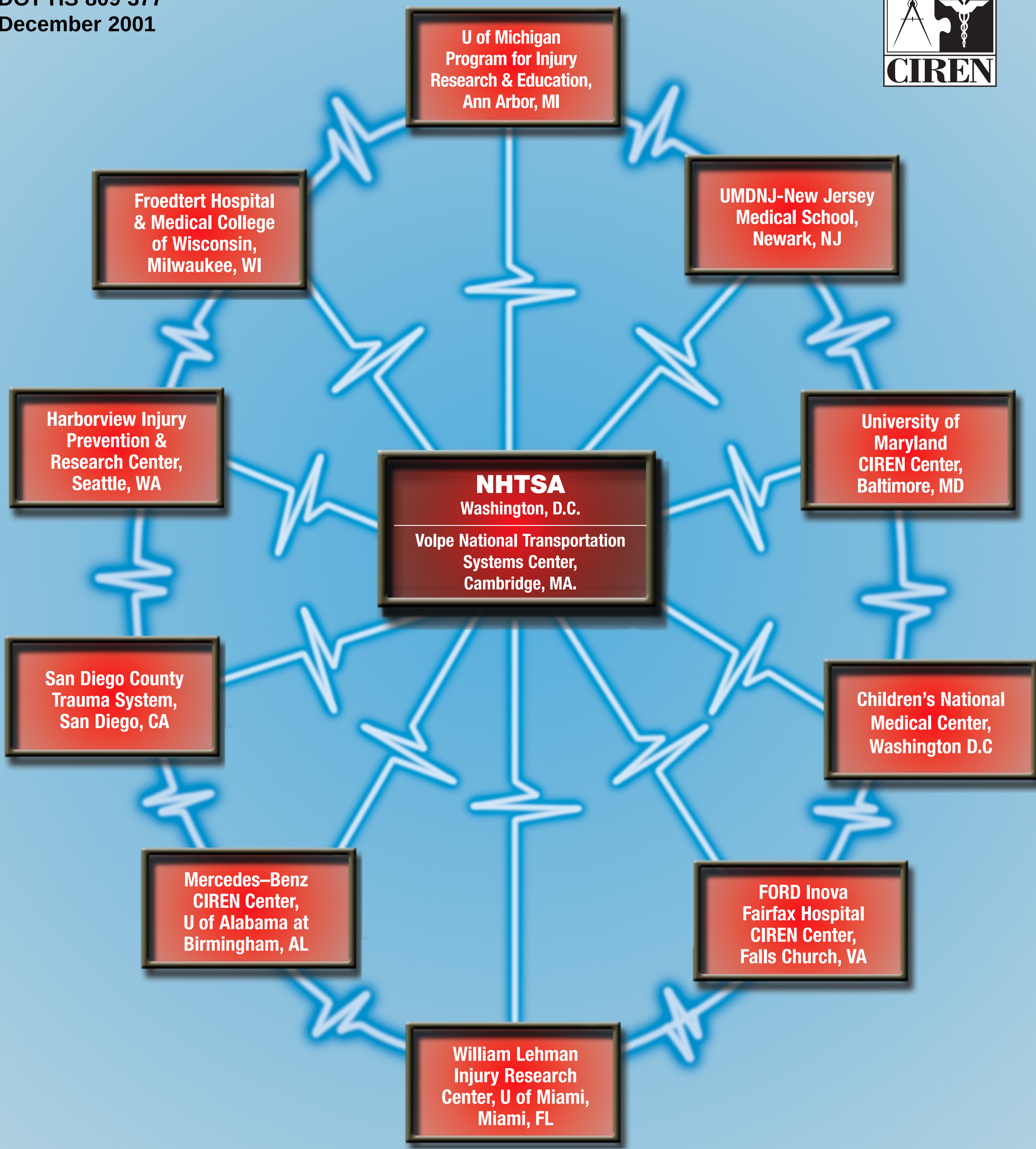

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