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

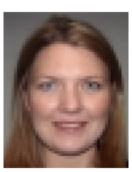
Pediatrics, the National SAFE KIDS Campaign, child restraint manufacturers, and other child passenger safety groups to design prevention programs, make technological improvements to restraints and vehicles, and to develop advocacy and policy recommendations.

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

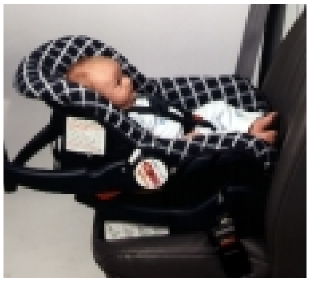


Figure 2
Convertible Seat
Rear-Facing

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

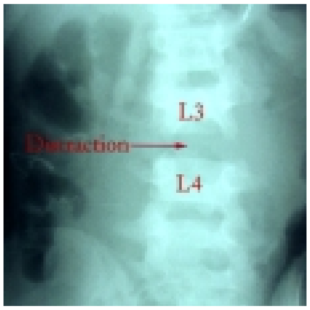
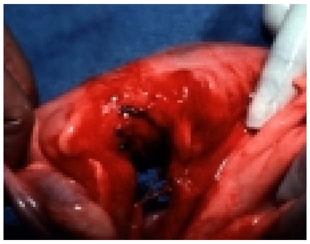
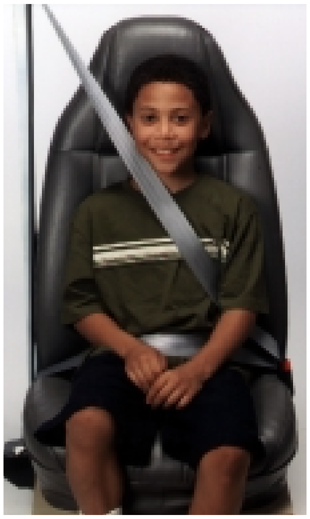


Figure 9
Intestinal Rupture



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

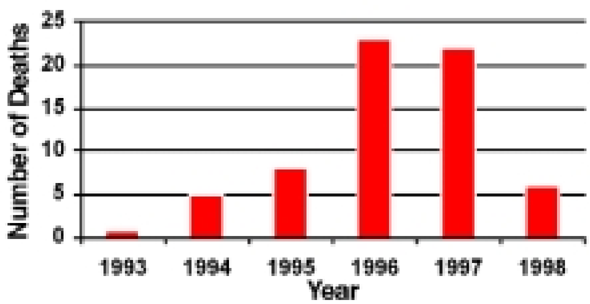
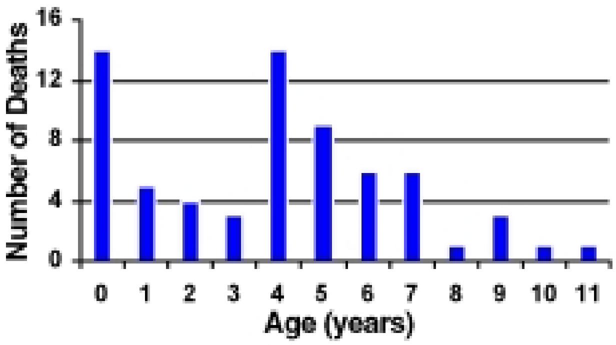


Figure 12
Airbag Deaths to Children by Age



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%)

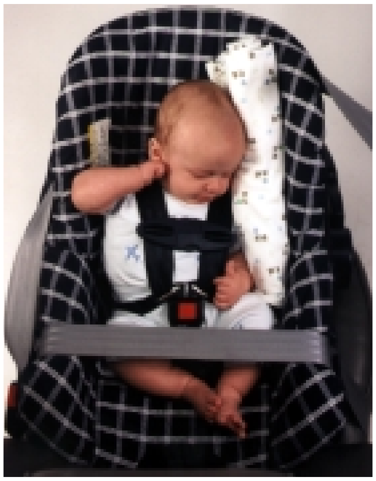


Figure 14
Common Misuses for Forward-facing Seats

- 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%.

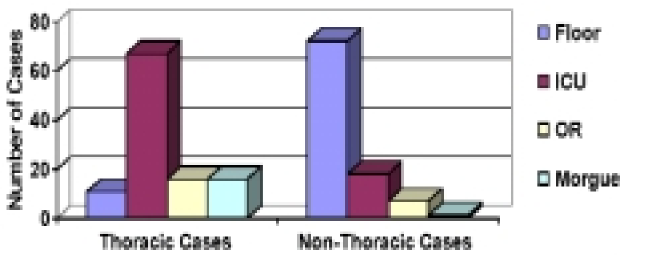
Motor vehicle crashes accounted for the most thoracic injuries (36%), but child abuse and falls accounted for the largest number of fatalities from thoracic injuries (26.9% and 12.8% respectively) compared to 12.4% for motor vehicles crashes. Of the 667 thoracic injuries, pulmonary contusions were the 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

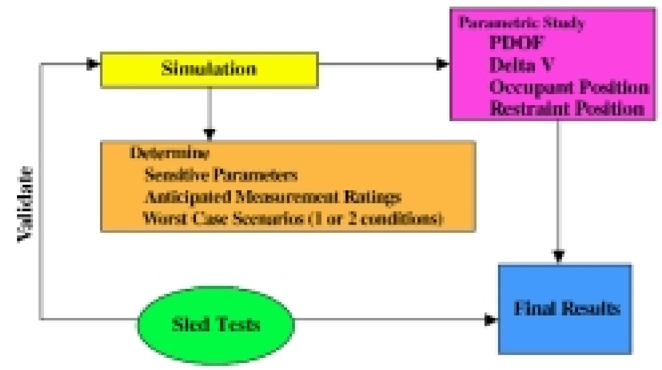
The CNMC CIREN site contracted with the University of Virginia Automobile Safety Laboratory (ASL) in May 2001 to use multi-body computer models to simulate the forces and related moments experienced by child occupants in car crashes. The objectives are as follows:

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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Bond SJ, Gotschall CS, Eichelberger MR. "Predictors of Abdominal Injury in children with pelvic fracture." *J Trauma*, 1991;31:1169-1173.

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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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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.

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