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.

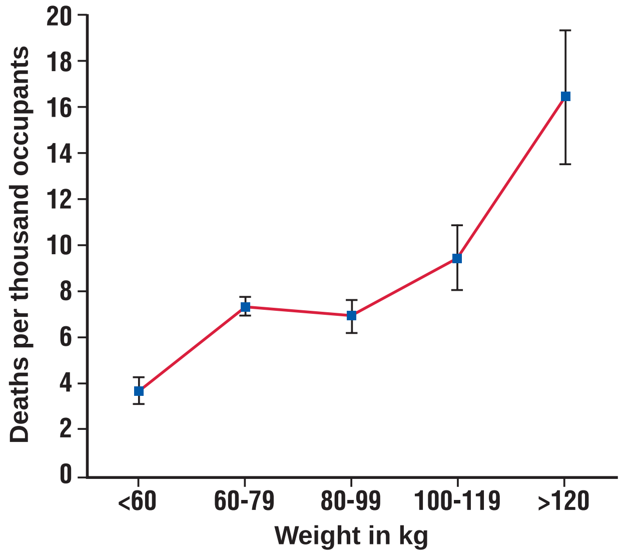
The study concluded with a call for increased awareness of this problem and for increased efforts to alert the public to the need to use lap belts along with automatic shoulder harnesses.

"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%.

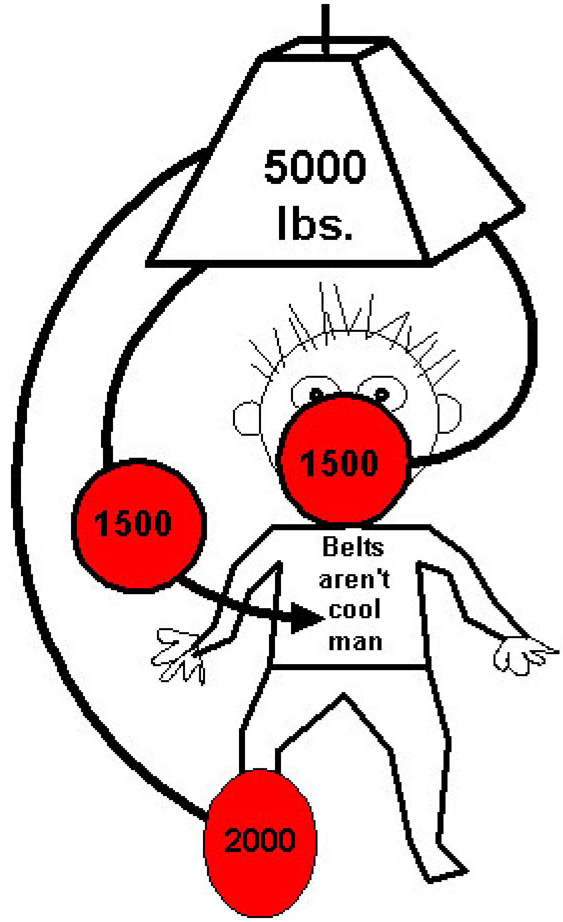
Two factors we propose might explain the discrepancy. The occupant's femur was out of position (typically the driver's right foot was on the brake) and did not impact the knee bolster, instead hitting stiffer regions around or on the steering column. The knee bolster (Figure F) is the region of the dashboard 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 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.

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.

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