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.

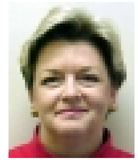
The present membership of the UMDNJ-New Jersey Medical School CIREN Center:

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.

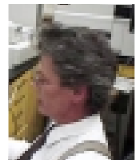
Coordinator: Joyce A. Smith, M.S., has worked with Dr. Siegel since 1985. She has a graduate degree in computer science and experience with research methodology and statistics. She is responsible for overseeing the daily operations of the study, as well as maintaining and upgrading in-house databases.

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.

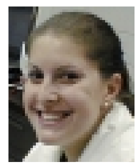
Psychosocial Research Associate: Ruth Ross, Ph.D., has been with the study since January 2001. She is involved with conducting psychosocial interviews with patients or family members and in analyzing the resulting data.



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

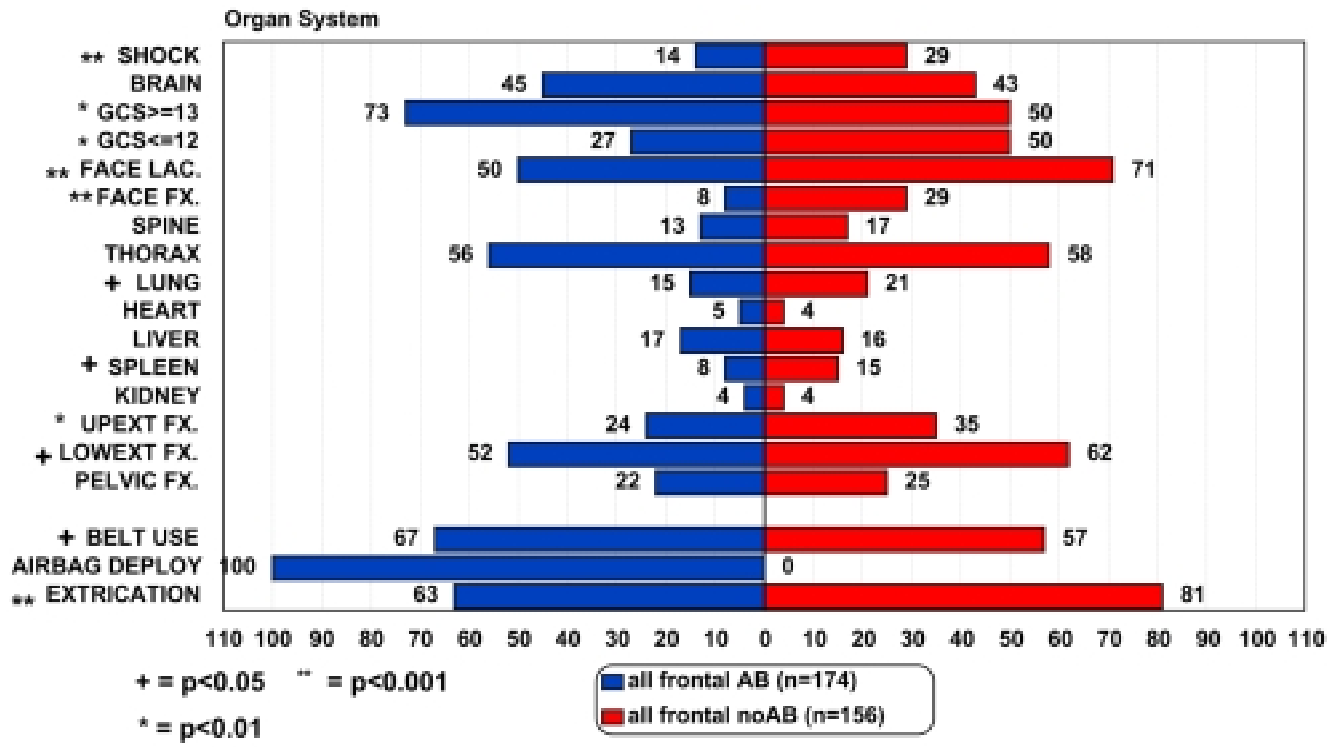
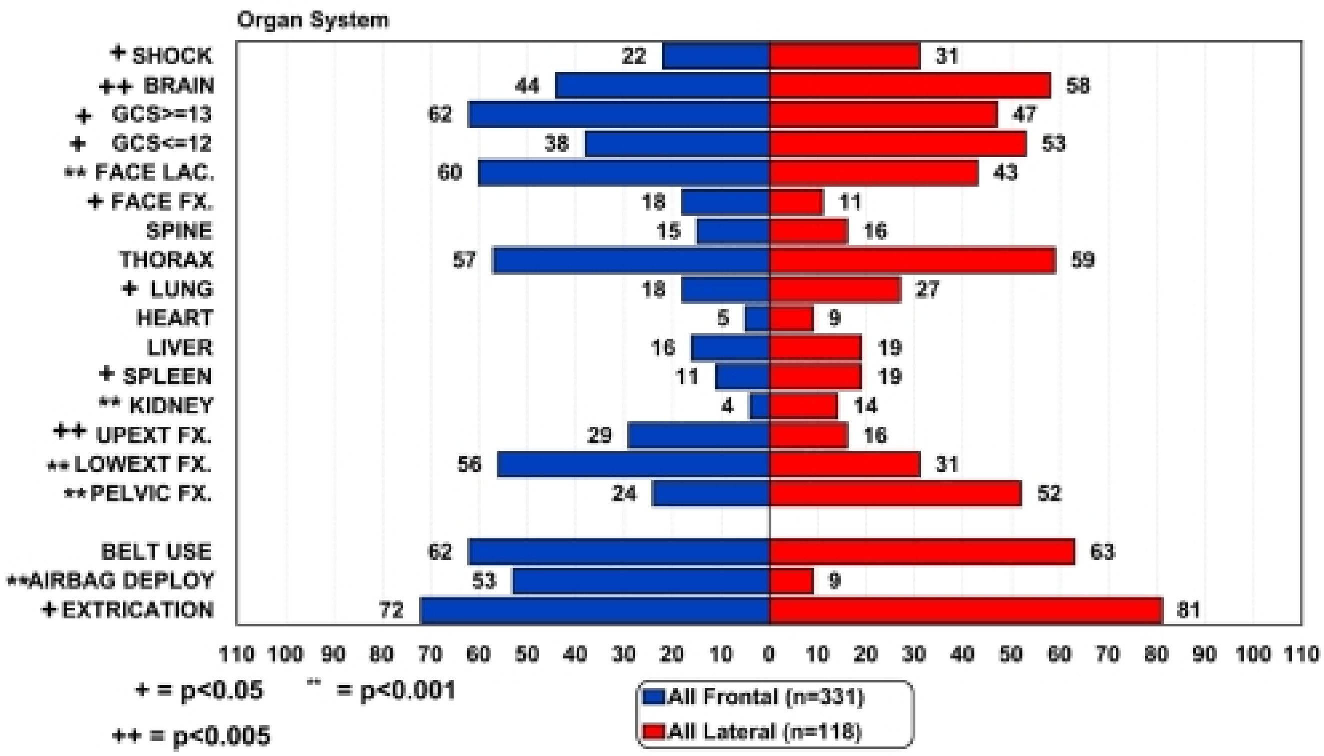


Figure 2:
All Frontal Cases vs All Lateral Cases



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

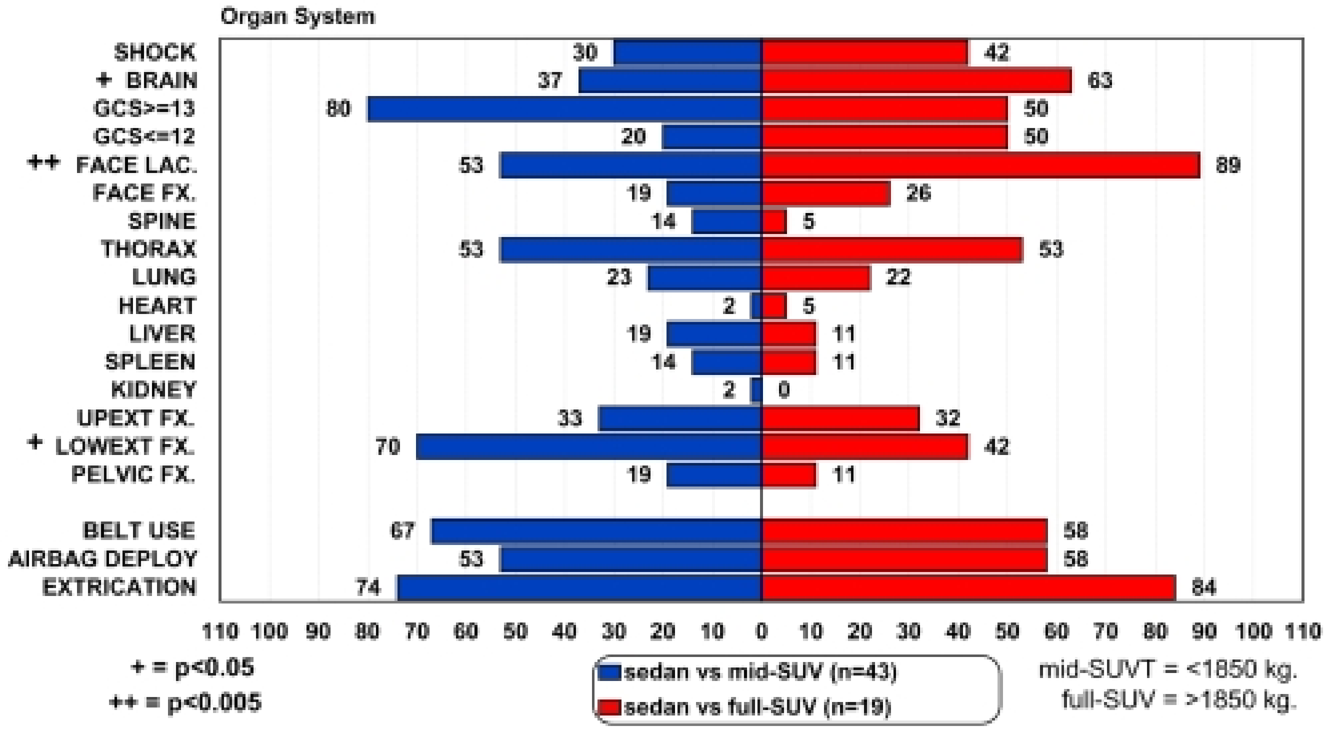
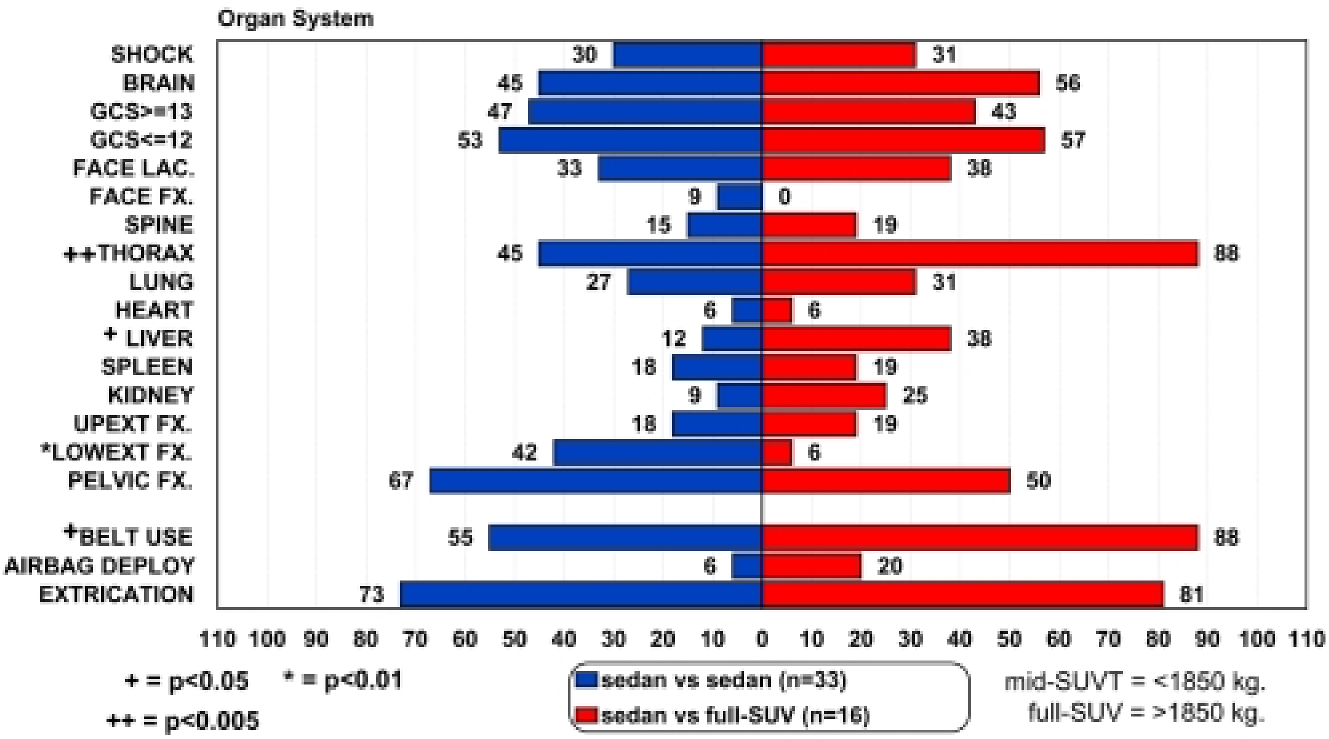


Figure 4:
Lateral Sedan/Sedan vs Sedan/Full-Size SUVT



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

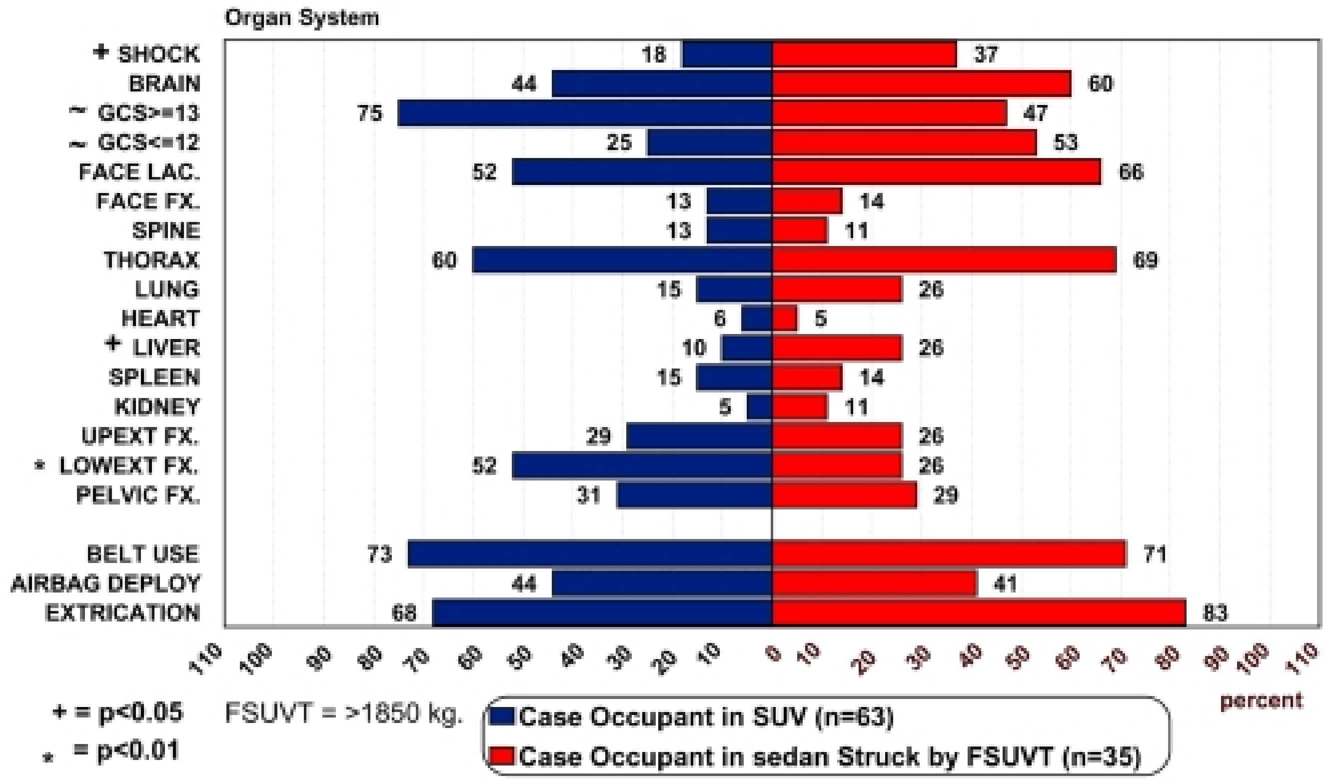
Detailed analysis of the structural data obtained from the crash reconstructions has shown that there are several factors that have significance in determining the alteration and severity in the pattern of injuries sustained by sedan occupants in crashes with SUVs, vans and light trucks (SUVTs). The 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 ≥ 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 ≤ 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.

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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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