William Lehman Injury Research Center

A CIREN CENTER

Prevention, Treatment, Rehabilitation

CIREN Program Report

Overview of a CIREN Center

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

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

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

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

CIREN Research Group

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

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

William Lehman Injury Research Center –THE CIREN TEAM

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

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

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

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

vehicle crashes and develops greater understanding of the need for improvements in safety and safety equipment.

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

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

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

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

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

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

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

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

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

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

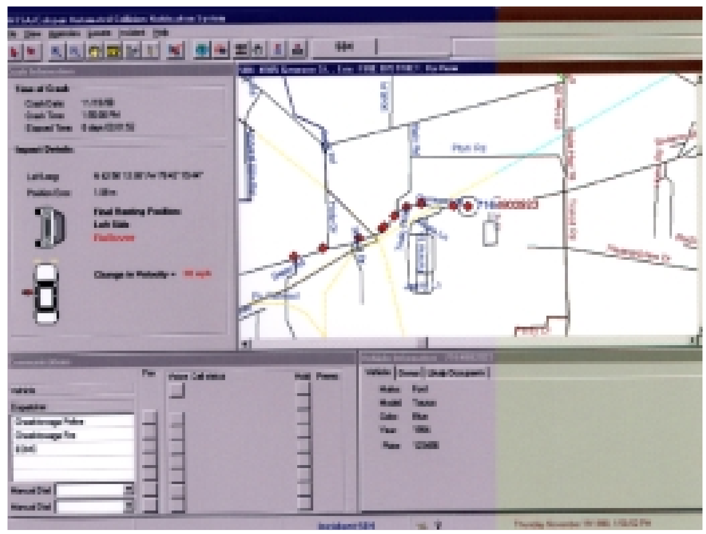
CIREN Contributions

By thorough analysis of CIREN and NASS/CDS data, combined with studies of crash tests, cadaver tests and computer modeling of crashes, the Lehman CIREN Center has identified certain crash modes that are likely to produce 'occult' injuries. These occult injuries are sometimes unrecognizable, based on physiological information available to the EMS unit. However, they can be fatal if undetected. EMS care providers that support the Ryder Trauma Center are currently in the process of being trained to recognize

high-risk crashes and triage people accordingly. Several papers have been published and presentations made to bring these crash injury models to the attention of the medical community. This research has led to the development of a computer algorithm (URGENCY) that is being used to predict the risk of serious injury and the presence of occult injury, based on information available from the vehicle and from crash scene.

URGENCY

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



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

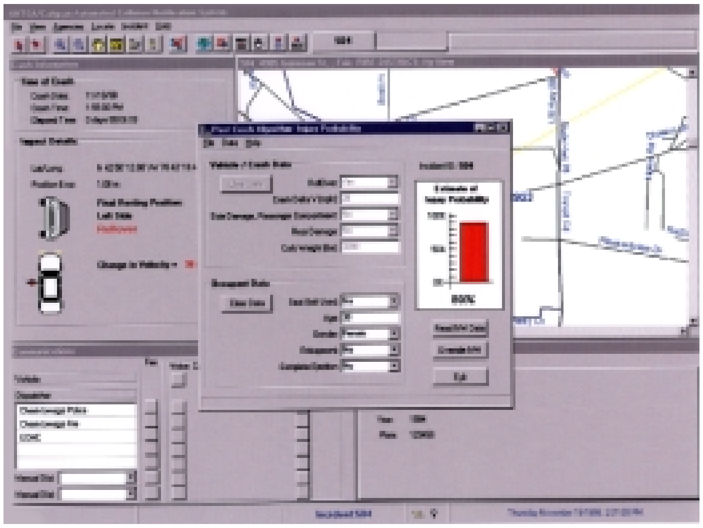
Combining existing crash sensors, global positioning systems, and wireless telephones allows immediate notification of emergency personnel in the event of a crash. The subsequent reduction in response time and dispatch of appropriate rescue personnel would result in improved patient outcome and a reduction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

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

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

Recognition of Crashes With High Risk of Serious Injury

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



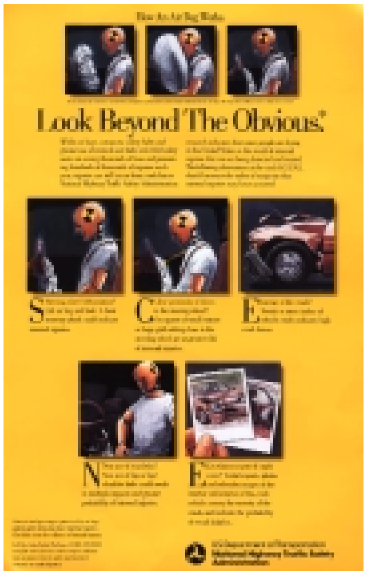
- Developed and improved URGENCY to predict injury risk based on observed data available from sensors on-board the vehicle.
- Published validation results for URGENCY in frontal crashes, based on CIREN data.
- Developed and published improvements for the URGENCY algorithm to improve its accuracy.

Side Impact Injuries

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

Occult Injuries

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



Air Bag Injuries

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

Lower Extremity Injuries

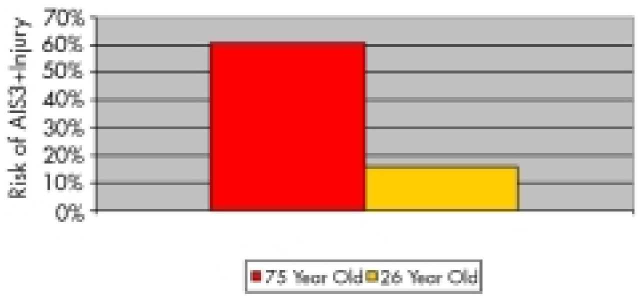
- Advanced the scientific understanding of lower extremity injuries, the associated crash forces, kinematics, and long-term impairment and disability.

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

Injuries Among Elderly Occupants

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

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



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

A New Research Tool

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Recognition of Crashes with High Risk of Serious Injury

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

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

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

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

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

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

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

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

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

A Scenario of the Near Future

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

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

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

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

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

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

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

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

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

Recent Presentations:

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

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

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

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

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

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

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

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

"Crash and Injury Patterns Among Occupants of SU.," Presentation in Ann Arbor, for National Meeting of CIREN, September 6, 2001.

Publications

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