NHTSA's Vision for Human Injury Research

Stephen A. Ridella
Shashi M. Kuppa
Peter G. Martin
Catherine A. McCullough
Rodney W. Rudd
Mark Scarboro
Erik G. Takhounts
National Highway Traffic Safety Administration
United States
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ABSTRACT

The Human Injury Research Division at NHTSA has a mission to conduct research to advance the scientific knowledge in impact biomechanics that enhances motor vehicle occupant safety and supports NHTSA's mission to save lives, prevent injuries, and reduce economic costs due to road traffic crashes. For over 25 years, NHTSA's research has helped to improve understanding of the mechanisms of human injury and the tolerance of the various regions of the human body to the mechanical forces resulting from a car crash. The crash dummies, injury criteria, and modeling tools developed under this research have enabled the agency to develop regulations and consumer information to make vehicles safer.

This paper will describe how analysis of crash field data and in-depth case analysis has helped to identify vulnerable populations of occupants as well as areas of the human body that require further research. Injury tolerance of the elderly, pediatric biomechanics, head and brain injury, and thoracic and abdominal injuries are examples of the projects that will be described. The use of advanced computer modeling techniques for assessing human injury and enhancements to current and future crash dummies will be discussed. Finally, a framework for carrying out this research plan will be shared with the intent to stimulate future ideas and collaborations.

BACKGROUND

The biomechanics research sponsored and conducted by NHTSA for the last three decades has resulted in significant advances in the knowledge of human impact response and injury tolerance. These advances have led to new crash dummy designs for frontal and side impact, dummy response requirements, associated injury criteria for head, neck, chest, and lower extremities, and the development of computer-based human models. This work has been implemented in Federal motor vehicle safety standards (FMVSS) to help improve vehicle crash and restraints performance and ultimately to improve safety for all motor vehicle occupants.

This work has not been done alone, but through the relationships developed at many institutions across North America, Europe, Asia, and Australia. NHTSA funding has helped foster and develop a generation of researchers in impact biomechanics who continue to dedicate their careers to understand better the human tolerance to vehicular crash conditions and help NHTSA achieve its mission.

In 2005, NHTSA engaged in discussions with industry and academic researchers and held extensive NHTSA inter-departmental meetings to develop a plan that would set the foundation for future biomechanics research sponsored by NHTSA. This plan is to be a continually evolving plan that considers input from all sources. For example, the IRCOBI (International Research Council on the Biomechanics of Injury, 2006) recently published a document outlining recommended research in impact biomechanics. This kind of input helps the NHTSA plan remain current and relevant. With these inputs in mind, the plan has set strategic objectives to be followed to achieve the plan's success. Those objectives are:

1) Conduct detailed analysis of NHTSA Data Systems (NASS, FARS, SCI, and CIREN) to determine injury severity and causation.
2) Prioritize and conduct necessary experimental research that identifies and/or improves the understanding of the mechanics of impact trauma in the automotive environment.
3) Pursue the development and application of advanced structural and statistical modeling techniques to obtain a better understanding of injury processes and improve the

agency's ability to predict the extent and severity of impact injuries.

4) Pursue detailed medical and engineering analysis of selected, real world, automotive crash events to identify causes and consequences of observed trauma and identify and/or monitor emerging field injury issues.
5) Develop new and improve existing test devices (dummies, impactors, instrumentation, etc.), to better represent the living crash victim and/or improve the means by which estimations of expected extent and severity of injury are obtained.
6) Promote and conduct necessary design, development, testing, and evaluation efforts to federalize biomechanical test devices to accelerate their introduction into NHTSA's evaluation and regulation activities.
7) Maintain a viable database of all NHTSA sponsored biomechanical test results to allow merging of experimental efforts and maximize statistical basis for conclusions derived from analysis of data.

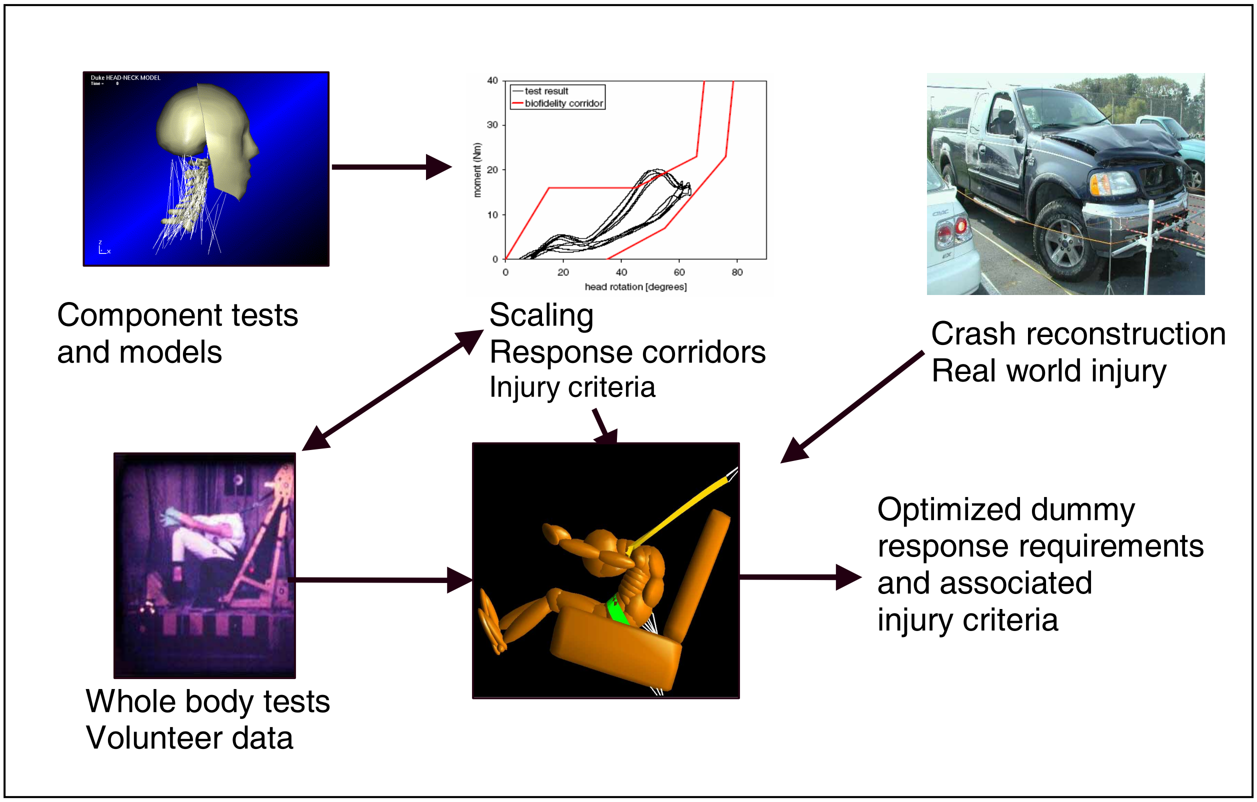

Figure 1: Flow Chart of Principal Methodology for Human Injury Research

Figure 1 shows a schematic as to how the items listed above flow into tangible deliverables that NHTSA and the industry can use to prioritize the safety efforts of vehicles. The following pages describe the initiatives to complete the objectives. Examples of the research and results will be given.

CRASH DATA ANALYSIS

Population-Based Data Analysis

A detailed analysis of NHTSA Data Systems was done to determine injury severity and causation. This analysis queried the National Automotive Sampling System (NASS) and Fatality Analysis Reporting System (FARS) for the years 1995-2004 covering vehicles with model year 1995-2005. The safety priorities for six different crash modes, nine types of occupants, and eight body regions were considered. The smallest fifteen percent (by height) of the adult population was considered to be represented by the 5th percentile female dummy and the largest fifteen percent of the adult population was considered to be represented by the 95th percentile male dummy. Occupant age 65 years and older were classified as elderly. The safety priority is based on frequency of injury, fatality attributable to a given injury, and disability and cost associated with a particular injury.

Table 1: Distribution of Occupant Involvement in NASS (1995-2004) Crashes (MY 1995-2004).

Occupant	Percent of Total
12 months	1%
3 years	1%
6 years	2%
10 years	4%
5^{th} Fem	12%
95^{th} Male	12%
50th Male	57%
Pregnant	<1%
Elderly	11%

Table 2: Distribution of Crash Modes in NASS (1995-2004) Crashes (MY 1995-2004).

Crash Mode	Percent Total
front	50%
side	27%
rear	5%
rollover	10%
pedestrian	3%
motorcycle	5%

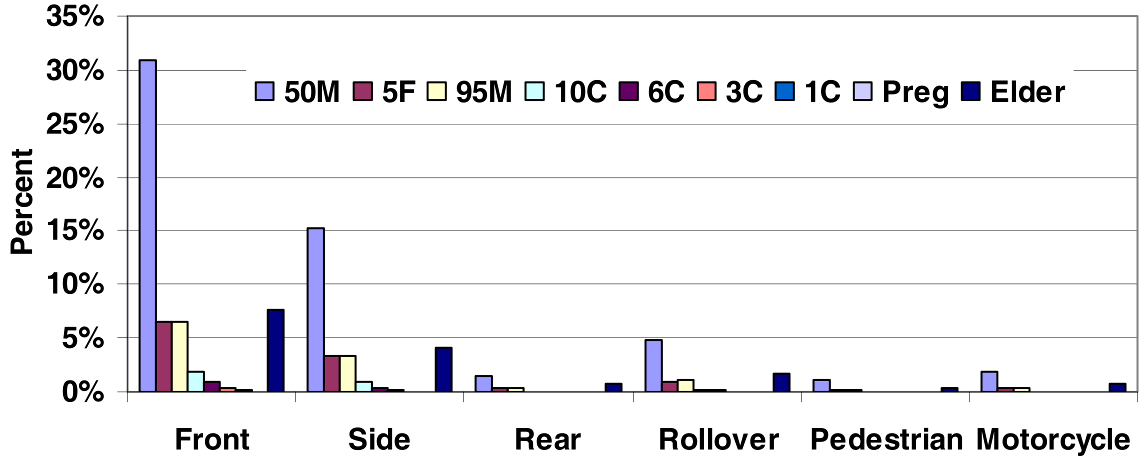

Figure 2: Distribution of Crash Involvement by Occupant Type (NASS 1995-2004, See Table 1 for Occupant Descriptions)

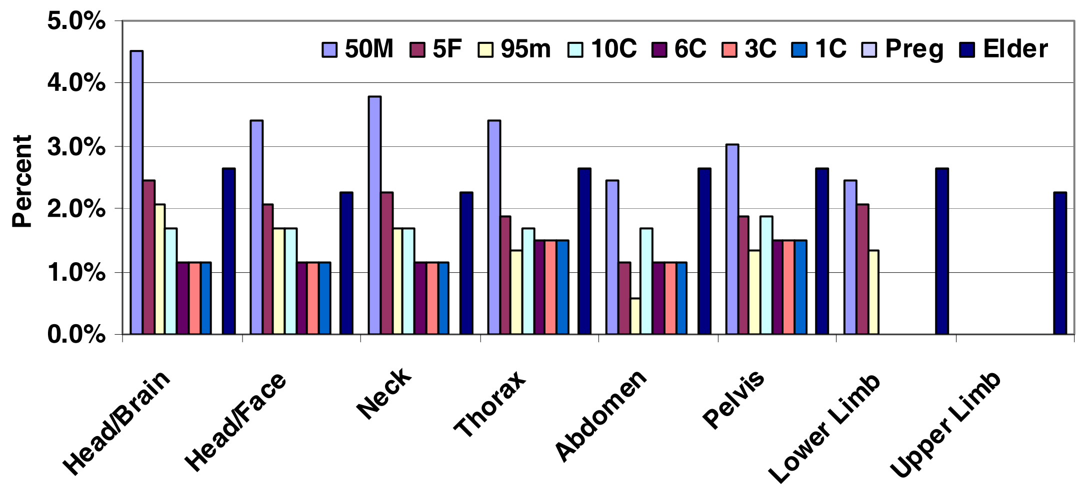

Figure 3: Distribution of Injury Locations by Occupant Type (NASS 1995-2004, all crash modes)

Tables 1 and 2 show the initial results of segregating crash involvement by occupant type and by overall crash mode. The dominant population groups involve the 50th percentile male, large male, small female and elderly. Children (classified by age) comprise a small, but not insignificant, subset of the total occupant population. For crash modes, frontal impact and side impact comprise over three quarters of all crashes in NASS, indicating that a continuing research emphasis is required for these modes. Further analysis of all crash modes by the frequency of involvement by the various occupant groups and the injuries they sustained is shown in Figures 2 and 3. The data indicates that frontal impacts are still a major concern for mid-sized males, and the elderly to a lesser extent, yet side crashes are a major concern also. In terms of injury locations, the various occupant groups show a high representation of head, neck, thorax, and abdominal injury.

More substantial injury analysis for frontal impact assessment was undertaken by Eigen and Martin (2005). They analyzed the NASS-CDS dataset to include only occupants with an MAIS injury greater than or equal to MAIS 2 (all AIS 1 injuries are disregarded) in vehicles of model year 1998 or later. Also, the dataset included for each case all the traditional descriptive variables (model year 1998 or later, vehicle type, crash type (front, near side, far side, rear, rollover), delta-V, occupant age (12 and older are considered to be adults), seat belt use, seating position, etc. The dataset ultimately resulted in 138,000 weighted NASS occupants and 2,800 weighted fatalities. The injuries were further classified and ranked according to comprehensive descriptions of the injuries as well as the cost and the fatality attributable to an injury (Blincoe, 2002). The result for costs and fatality attributed to an injured body region is shown in Figure 4. This result indicates that the head and chest injuries are responsible for most fatalities while lower leg and head injuries incur the most cost. These results have helped to address the research areas that the NHTSA is pursuing currently.

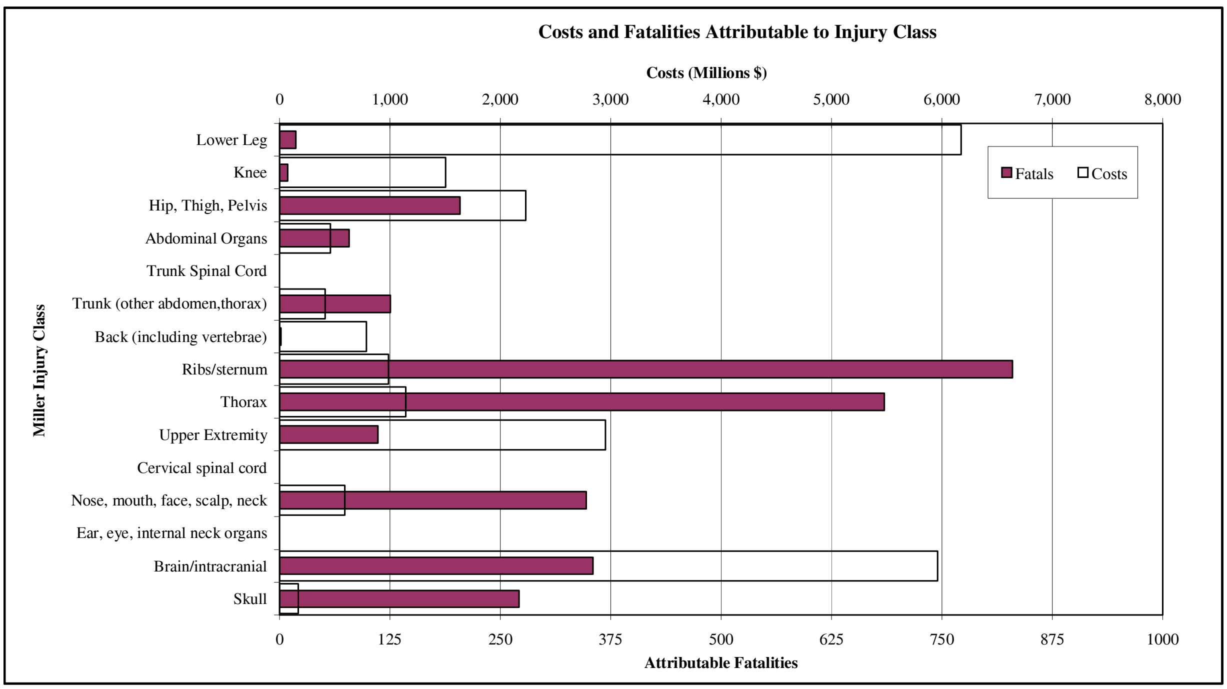

Figure 4: NASS-CDS Analysis of Cost and Fatalities Attributed to Injured Body Regions (see Eigen and Martin, 2005 for additional details)

CIREN Program Enhancements

To gain additional insight into injury causation and mechanisms, the Crash Injury Research and Engineering Network (CIREN) has become integrated into the Human Injury Research Division. For over ten years, CIREN has been a sponsor-led, multi-center collaborative research program that focuses on in-depth studies of serious motor vehicle crashes. Researchers collect and analyze crash and injury data in order to improve vehicle design and the treatment and rehabilitation of crash victims. One of CIREN's stated goals is to use this information to reduce crash injuries, deaths, disabilities, and associated societal and economic costs.

CIREN began a new chapter in 2005 with new performance-based cooperative agreements for six NHTSA-funded centers spread across the United States joined with two industry-funded centers. The six NHTSA-funded centers are: Children's Hospital of Philadelphia, Medical College of Wisconsin, University of Maryland-Baltimore, University of Michigan, County of San Diego – Health and Human Services and Harborview Injury Prevention and Research Center (Seattle). The new Toyota-funded center at Wake Forest University School of Medicine in Winston-Salem, North Carolina joins the existing Honda-funded center at Inova Fairfax Hospital in Fairfax, Virginia.

CIREN data is being analyzed at all centers and throughout NHTSA to learn even more about crash injury than ever before. Two new initiative, BioTab and DICOM image collection (described below) will add even more insight.

The Biomechanics Tab or BioTab of the CIREN database provides a means to completely and accurately analyze and document the physical causes of injury based on data obtained from detailed medical records and imaging, in-depth crash investigations, and findings from the medical and biomechanical literature. The BioTab was developed because the terminology and methods currently used to describe and document injury causation from crash investigations are sometimes vague and incomplete. For example, the terms "direct" and "indirect" loading are often used to describe how an injury occurred. However, there are situations where these terms are unclear, e.g., is a femoral shaft fracture from knee-to-knee bolster loading from direct loading of the knee or indirect loading of the femur through the knee? In addition, the term inertial loading is often used to describe how tensile neck injuries occur, however, using this terminology fails to document that neck tension would not have occurred unless the torso was restrained. The BioTab removes these ambiguities by providing a consistent and well-defined manner for coding injuries and recording the biomechanics of injury in crash injury databases. It also allows the identification and documentation of factors that led to a specific AIS 3+ injury such as:

1) Whether the injury was caused by another injury (e.g., a rib fracture causes a lung laceration),
2) The Source of Energy (SOE) that led to the occupant loading that caused the injury (crash, air bag, etc.),
3) The Involved Physical Component (IPC) that caused injury by contacting the occupant and the body region contacted by the IPC, and
4) The path by which force was transmitted from the body region contacted, through body components, to the site of injury.

This effort is particularly noteworthy since this will lead to a greater understanding of crash kinematics and injury mechanisms. Users of other NHTSA crash data collection systems have requested to be trained on the use of this coding technique.

Starting in 2006, CIREN centers began collecting 2-D and 3-D DICOM (Digital Imaging and Communications in Medicine) images of all case occupants. DICOM image sets are a standard medical industry method of collecting digital images (e.g., Computed Tomography, CT) of patients. These images may be assembled to allow two and three dimensional views of injured case occupants that will shed further light into the understanding of injury causation and mechanisms. Figure 5 shows an example of a 3-D DICOM reconstruction.

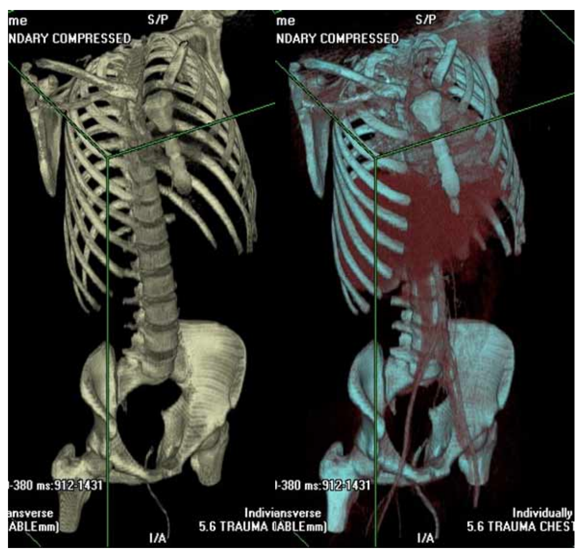

Figure 5: DICOM reconstruction showing bone and organ detail.

With the rich detail of these images, it will be possible to use them to better define human anthropometry in terms of bony geometry, fat and muscle thickness, and organ location. By studying hundreds of such images, NHTSA researchers will be able to understand the human anatomical variability as it relates to injuries suffered in car crashes. The images will be used to create better defined human finite element models that represent this vast range of human variability in ways that have not yet been attempted. Work is underway to catalog and create standard measures that can be translated into a database for future research. It should be noted that for legal and ethical reasons, all personal data associated with any image collected have been removed.

One example of how CIREN data has been used by NHTSA is represented by the work by Rupp et al (2002). Based on the prevalence of knee-thigh-hip (KTH) injuries and the associated injury causation, Rupp performed research that has led to a proposal for a KTH criteria to assess occupant protection in the NHTSA's New Car Assessment Program (NCAP) (NHTSA,2006). Additional examples of such work are underway for other body regions and that will be described below.

INJURY MECHANISMS AND CRITERIA RESEARCH

To meet objectives 2 and 3 listed in the Background section above, NHTSA engages several institutions to conduct impact trauma research to understand the human body component and system response to these impacts. The crash data from NASS and CIREN indicate the priorities of what body regions should be researched and the research plan is made accordingly. With the data gathered from the research performed by funded institutions, NHTSA uses statistical methods to generate injury risk curves that can be used in the development of potential injury criteria for application to a crash dummy subjected to a similar loading condition. The following are examples of research areas that NHTSA is investigating through its collaborations with research institutions.

Head/Brain Injury

In the analysis of real-world car crashes, head and brain injuries were still a major source of cost and fatality even in later model year vehicles (Figure 4). Researchers place head and brain injuries into three broad categories: those manifested by rotation only (such as diffuse axonal injuries), those manifested by translation with impact (such as skull fractures), and those manifested by a combined rotation/translation.

With that premise, NHTSA is trying to develop a better understanding of the head and brain injury mechanisms. Research is underway to review existing information and to generate needed experimental data to elucidate the mechanics and detection of skull fracture and closed brain injuries (i.e., diffuse axonal injury, focal injuries, and acute subdural hematomas). Both adult and pediatric brain injury mechanisms will be studied.

NHTSA continues to develop a tool for assessing the potential for brain injury in vehicle crash tests. The SIMon program (Simulated Injury Monitor, Takhounts et al, 2003) was developed to bridge the dummy response to the human response and probability for different brain injuries. SIMon (Figure 6 shows updated model) has been tested in many different areas and is even being used in reconstruction of brain injuries in real vehicle crashes (Hasija et al, 2007). In another funded research project, data is collected from accelerometers embedded in the helmets of football players as they are playing. This data is to be fed into the SIMon program to assess the potential for the SIMon parameters to predict the potential for mild traumatic brain injury that is sometimes suffered by these players.

It is the intent of the brain research to suggest injury criteria and injury threshold levels for brain injury assessment that may be used by NHTSA to further reduce the head injuries seen in the field. In February, 2007, NHTSA hosted a Brain Injury Symposium which gathered over 100 lead brain injury experts to determine short and long term research goals based on the current understanding of the issues.

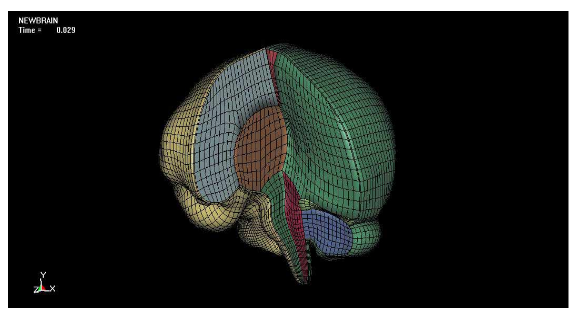

Figure 6: Enhanced SIMon Brain Model

Thoracic Injuries

In spite of the advancement in occupant restraint technology such as force limiting belts, pretensioners, and advanced air bags, thoracic injuries remain a frequent injury in frontal crashes, particularly to the elderly. This research program examines thoracic response and injury criteria for assessing thoracic injury risk in different restraint environments. The research program in this area will include human cadaver and surrogate testing. Attempts will be made to assess local phenomena correlated with specific injury patterns as opposed to generic thoracic injury predictors. Specifically, injury thresholds (deformation-based or other physical parameters) for various thoracic organs (aorta, liver, spleen, heart and lung) will be assessed. The culmination of this research may provide the information necessary to suggest new impact response requirements (torso and organ level) and improved injury criteria for assessing injury risk in current restraint environments. This research will help improve the ability of frontal crash dummies and other human surrogates to assess the real-world performance of current and future restraint systems.

Particular attention will be paid to thoracic injuries to the elderly occupants in different restraint environments to assess which restraints are more likely to be used (comfort-based) and beneficial (injury-based) to the elderly in frontal crashes. In addition the restraints of rear seats are evaluated using human cadaveric subjects and advanced dummies. The efficacy of improved rear seat restraints is being examined as well.

A new system of evaluating cadaver and dummy thoracic and shoulder response has been developed. Sled tests are being run on a simplified universal buck to facilitate 360 degree visualization of the impact event. The buck will be generic in nature and will be sufficiently simple to serve as a standardized evaluation tool at multiple laboratories. Preliminary dummy and cadaver tests conducted with a standard belt system have confirmed the viability of using a

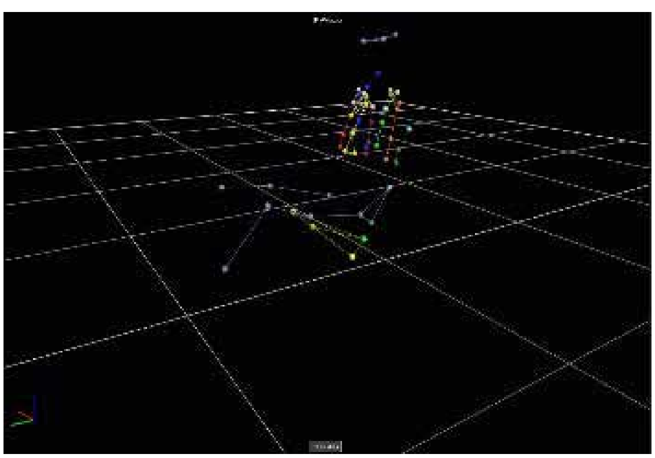

Figure 7: Vicon™ Camera Image of Targets on Dummy (oblique view)

multiple Vicon™ motion-analysis camera system to record thoracic kinematics and deformation (Figure 7). By testing cadaver and dummy surrogates with a variety of standard and force limiting belt conditions, an overall assessment of cadaver and dummy response will be done. This could lead to future improvements in injury criteria and dummy design.

VULNERABLE OCCUPANT INJURY ANALYSIS

Child occupants

A dedicated research effort in understanding child occupant injury patterns and tolerance has been ongoing at NHTSA for many years. The research led to the development of new injury criteria that are now part of FMVSS No. 208 and other standards. A renewed emphasis on child safety is underway as data has showed that motor vehicle crashes are the primary cause of death for children over 4, adolescents and teenagers. In 2005, NHTSA began coordinating meetings between a number of research labs involved in child passenger safety research. These meetings have led NHTSA to fund a number of projects with the intent of creating better understanding of pediatric impact response and in 2006, a more detailed project plan was created. These projects include the following:

1) Pediatric neck response and injury tolerance
2) Pediatric head injury analysis
3) Pediatric spinal kinematics
4) Pediatric thoracic response and compliance
5) Assessment of pediatric pelvic geometry

The objectives of this combined research are to determine potential child dummy enhancements that could be implemented so that dummy responses better mimic actual child responses. It is also desirable to have injury criteria consistent with tolerance directly measured from pediatric tissue. It may also be possible to support the creation of a child human computer finite element model with the data from these projects. A coordinated effort is needed to better understand this issue.

Elderly Occupants

Real world crash data indicates that elderly vehicle occupants generally have lower impact tolerance than younger occupants (Kent et al, 2003). In addition, the elderly often suffer from pre-existing conditions making them unable to recover as quickly or easily from injuries sustained in a crash. In particular, the data indicates a significantly greater risk of thoracic injury to the elderly compared to younger occupants while there is no significant difference in injury risk exists between groups for other body regions.

NHTSA is developing an approach to understanding the elderly crash injury response with a program aimed at the following:

1) Analysis of CIREN Data
    a. Perform data analysis from NASS-CDS and CIREN data on elderly occupants to compare injury trends in the two databases.
    b. Analyze CIREN data regarding injury causation and injury mechanisms for older case occupants compared to younger case occupants.
    c. Use advanced medical imaging data captured on CIREN subjects to analyze how human body geometry and composition changes with aging and assess its impact on injuries.
2) Research Related to Human Injury and Assessment of the Need for an "Elderly" Dummy
    a. Research on elderly injury tolerance through the testing of human surrogates and different size dummy tests with current and advanced restraint systems.
    b. Feasibility of developing injury criteria based on age.
    c. Determination of need for "elderly" crash dummy based on data analysis and available research results.

This research effort will be done both internally at NHTSA research and in collaboration with research institutions that have experience with elderly injury mechanisms and response.

ANTHROPOMETRIC TEST DEVICE RESEARCH

NHTSA has long engaged in the development of anthropometric test devices or crash test dummies. The Federal motor vehicle safety standards stipulate over a dozen crash dummies and dummy components required for testing in a frontal, side, and rear impacts as well as component level tests to evaluate vehicle crashworthiness and occupant protection. These vital tools have helped vehicle manufacturers and suppliers design safer vehicles and restraint systems for many years. The following discussion describes current crash test dummy research at NHTSA.

WorldSID Evaluation

To assess the potential for incorporating the WorldSID dummy into part 572, CFR 49, NHTSA has been analyzing the biofidelity, repeatability, reproducibility, oblique impact sensitivity, temperature sensitivity and overall performance of the dummy. The NHTSA Vehicle Research and Test Center (VRTC) began testing with the WorldSID 50th Percentile prototype dummy in 2001, using a dummy on loan from the WorldSID Committee. The prototype dummy demonstrated improved biofidelity over all currently existing 50th percentile male side impact dummies, although the pelvis response appeared to need improvement. In August 2004, two production WorldSID dummies on loan from the WorldSID Committee were delivered to VRTC for evaluation testing. VRTC personnel and the WorldSID committee met and agreed to the VRTC evaluation plan. VRTC and the WorldSID committee continue to evaluate and develop the dummy in a cooperative effort.

THOR Advanced Frontal Crash Dummy

Final design drawings for THOR-NT (New Technology) were released to the public in July 2005. The NT version of THOR (Test device for Human Occupant Restraint) incorporated many design changes after the initial release and testing evaluation of THOR Alpha in the late 1990s (Shams et al, 2005). THOR-NT represents the culmination of a project that can trace its beginnings to the advanced dummy projects that NHTSA began in the early 1980's. Since that time, there has been a substantial increase in available anthropometric and biomechanical data that has been incorporated into THOR. THOR is meant to be used to test the emerging advanced restraint systems that are being incorporated into vehicles. With its increased ability to measure neck, chest, abdominal, pelvic, and lower extremity loads, THOR seems well suited to evaluate the capability of these new safety systems.

Since 2005, there have been many industry tests and evaluations of the existing THOR-NT dummies. These data are being analyzed by NHTSA and others to determine if THOR is meeting its design targets. Industry groups in Europe and the U.S. have been meeting regularly to understand the results and to undertake continued testing and analysis of THOR that could lead to an international agreement on a future uses for this frontal impact dummy.

In addition to the 50th percentile male THOR-NT, a 5th percentile female THOR-NT prototype is nearing completion. This dummy will have an improved neck design that mimics the geometry and curvature of the human neck. Currently, the neck design is undergoing prototype testing and will be used in whole dummy out-of-position tests in order to assess its performance capabilities.

Child Dummies

Currently, the Hybrid III 3-year old and 6-year old dummies are used in FMVSS No. 208 out-of-position tests, FMVSS No. 213 frontal sled tests, and have been used for research purposes in the rear seats of NCAP frontal rigid barrier vehicle crash tests. The child dummies are also used in the side impact air bag out-of-position tests. More recently, the Hybrid III 10-year old dummy was proposed by NHTSA to evaluate booster seats as part of Anton's Law.

The Hybrid III type child dummies are scaled versions of the HIII-50M (Hybrid III 50th percentile male dummy) based on scaled biomechanical impact response requirements using previously published scaling methods (Mertz et al, 1997). Regional anthropometry differences and dynamic response differences between children and adults indicate the need for further research. Because of this potential difference, NHTSA is funding a study of child anthropometry to suggest improvements in child dummy design and performance. In addition, work is being carried out to better understand the thoracic, individual rib, and abdominal responses of children in a variety of funded programs. Direct measurement of such properties will lead to more biofidelic dummy designs than could be achieved with scaling methods. This methodology is also being applied to the dummy head and neck properties also.

The TREAD Act requires NHTSA to consider and make recommendation to Congress on the need for and current feasibility of a side impact child dummy and test procedure. The Agency recommended further research primarily because a test procedure and a suitable dummy do not exist. The Q3s child side dummy has been developed in Europe and is being evaluated by VRTC. The intent of the evaluation is to assess the Q3s for biofidelity and usefulness for injury assessment and to work with appropriate national and international organizations to effect needed revisions based on the best available human response data.

COMPUTER MODELING IN INJURY BIOMECHANICS

The impact of computer modeling technology on the safety and crashworthiness of vehicles has been dramatic and continues to grow. The influence of faster computing power and increased storage capacity has allowed the creation of vehicle models and crash dummy models that can be used to develop vehicle crashworthiness and occupant safety.

Dummy modeling

Computer models of current Hybrid III crash dummies have been commercially available for many years. To evaluate dummies under development, such as THOR, a finite element model can be a useful tool to compare responses in different loading conditions and to help identify potential design improvements.

A three-dimensional finite element model was developed to represent the response of the THOR thorax (model named THOR-X). Three dimensional CAD drawings of the THOR hardware were used to construct the geometry of the model. Most of the components were modeled as rigid bodies, with the exception of elastomer (shoulder and neck bumpers, flex joints, jacket and bib), foam material (upper abdomen and mid-sternum), and the steel ribs. The rigid bodies that moved relative to each other were connected with joint elements; a variety of contact definitions were used to define the interaction between rigid bodies and deformable materials. The finite element model outputs the same measurements as the THOR Crux (Compact Rotary Unit) device, that is, deflection units in four locations and one accelerometer located on the mid-sternum of the dummy. The completed finite element model was correlated with the physical THOR by simulating two Kroell impacts; one at 4.3 m/s and the other at 6.7 m/s and comparing model to experimental results. The force deflection curves for impactor force vs. chest deflection derived from the simulation compared well with those obtained from experimental data (Figure 8). It was concluded that the THOR-X finite element model can be used to accurately predict the results of physical tests performed with the THOR.

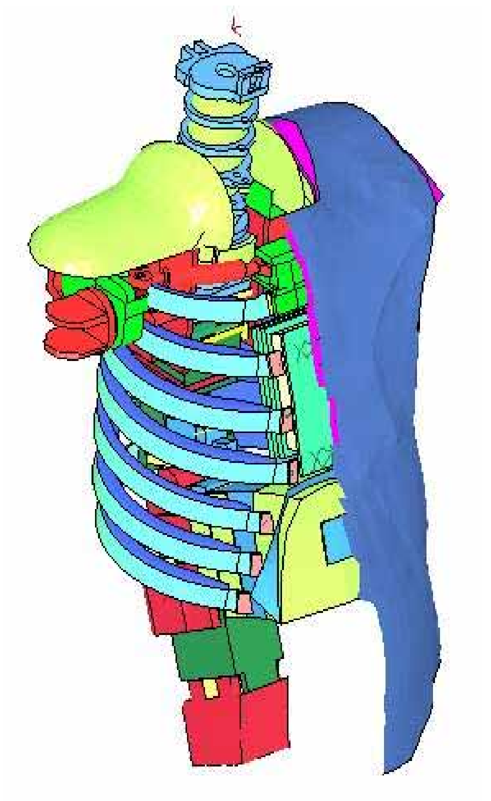

Figure 7: THOR Thorax Finite Element Model (THOR-X)

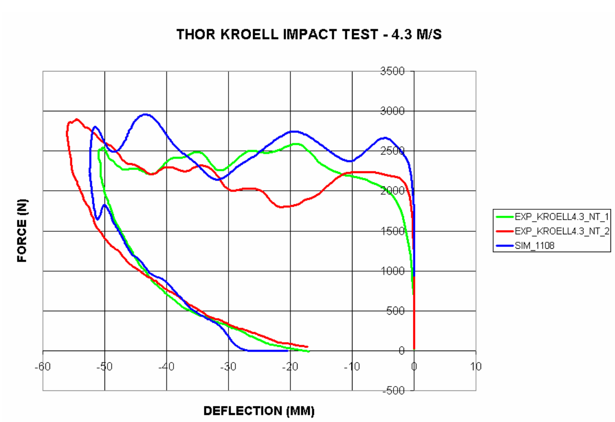

Figure 8: THOR-X Model (blue) Comparison to Weighted Pendulum THOR Dummy Impact Tests (red and green)

Human modeling

NHTSA has been involved in modeling human impact response since the early 1990s. Early versions of human head, brain and chest models were created and validated (Plank al, 1994 and Bandak et al, 1994). Since that time, significant enhancements in computing power and memory capabilities have allowed the creation of whole human body finite element models. These models are used in the automotive industry to understand the human impact response in a simulated crash environment. The proliferation of such models has led to a call for a set of unified models that can be used by the industry. This endeavor may find the biomechanics research data collected by the Human Injury Research Division useful as it develops its human computer models.

DATA ARCHIVE AND SUMMARY

The value of the research above is the variety of tools and products that are derived from the work. To satisfy objective 7 above, the research data itself is maintained in the NHTSA Biomechanics Database for all interested parties to download and use. NHTSA uses this data to create injury risk curves and criteria. The dummy components, dummies, and computer models are made available to the automotive safety industry for use in the development of safer vehicles. In this way, the mission of NHTSA, to reduce crash related fatalities, injuries, and their associated costs is fulfilled.

The plan for human injury research outlined here is meant to be fluid, not static. Continued acquisition of field crash data and experimental results, discussions with industry, academic, and other interested groups, and influences of government objectives, will help shape future research plans. Publication of results and presentations at all major biomechanics conferences is desired to achieve maximum dissemination of results and feedback on future directions.

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