A COMPREHENSIVE SURVEILLANCE SYSTEM TO INVESTIGATE TARGETED ISSUES IN CHILD OCCUPANT PROTECTION

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ABSTRACT

Current databases relating information about children in vehicle crashes are not comprehensive due in part, to the small sample sizes of these studies. This limitation has led to a focus on case series analyses, which have in turn produced few statistically based recommendations for vehicle and child restraint design changes. The magnitude of the problem of child occupant protection is not clear and limited mechanisms currently exist by which to systematically and thoroughly investigate critical questions in the field.

To address these issues, we have created a comprehensive surveillance system devoted exclusively to children riding as occupants in motor vehicles through the utilization of current insurance claim settlement procedures. This surveillance system will provide a mechanism for the prompt identification of important "targeted issues" that require more detailed investigation and analysis. These targeted issue studies will utilize crash investigations and telephone interviews to learn more details about crash circumstances, occupant kinematics, and restraint system performance. The unique combination of the surveillance system with these focused investigations will result in a statistically based sample with valid and generalizable results.

INTRODUCTION

The majority of automotive safety research has focused on the adult driver (1-4). Laboratory crash test data have typically studied the "50th percentile" male (5-7). The best real-world data available on the effectiveness of various restraint systems, such as lap belts, lap-shoulder belts, and air bags, are almost entirely on vehicle drivers. It is not known how data on driver protection may apply to vehicle passengers, particularly children.

Recently, child deaths associated with air bags (8) have focused attention on the fact that children are not just small adults and that research efforts must continue to concentrate on the specific needs of our smallest passengers (9-19). The data collected on how and why adults are injured in vehicle crashes do not always apply to children, who have smaller body frames, are proportioned differently, and have different injury patterns and tolerance levels to injury than do adults.

Many studies that have examined child occupant protection have looked primarily at mortality as the measured outcome. Death is easy to define and mortality data appear in a variety of readily available sources, including the National Center for Health Statistics, and the Fatal Analysis Reporting Systems (FARS) maintained by the National Highway Traffic Safety Administration. As a result, many studies that have identified child-specific risk factors, examined the effectiveness of restraints, and measured potential deficiencies in current restraint system-vehicle interactions have largely used mortality as the outcome of interest (2,4,20-23). However, because child occupant mortality is relatively rare (9.4 deaths per 100,000 children), examining only mortality as an outcome fails to capture the full impact of childhood injury and its potential long-term consequences (24).

Existing research that has focused on child occupant protection using injury as an outcome can be broadly categorized into three types, each having its own unique strengths and limitations: laboratory-based research, hospital-based research, and research using large databases.

Laboratory-based research explores restraint systems and vehicle design features as they pertain to child

occupant protection under well-controlled laboratory conditions (6,7,25,26). Child dummies or other surrogates are placed in simulated crash situations in order to measure both the forces of impact on the child occupant and the related kinematics. The strength of these studies is their ability to provide detailed information on the occupant kinematics as well as their capacity to base design specifications on engineering principles. However, these studies are often limited by their lack of a comparison group and by the artificial nature of the laboratory environment, in particular, the limitations of child-sized test dummies (27). The real-world relevance and applicability of these studies is, therefore, largely unknown (28).

Hospital-based research is conducted at one or possibly a small group of hospitals, typically designated trauma centers, and generally focuses on how a limited number of factors, such as seating location and restraint use, affect risk of injury (29-34). The strength of these studies is their ability to control the quality of data obtained, but the inherent biases in studying populations of children referred for specialty care often challenges the validity and limits the generalizability of these studies' results and conclusions. In addition, hospital-based research typically examines a relatively small sample, making it difficult to account properly for the complex nature of motor vehicle collisions and the many potential predictors of injury to children.

Research using large, existing databases, most notably in the United States, the National Highway Traffic Safety Administration's National Automotive Sampling System (NASS), has attempted to overcome the biases associated with hospital-based research by including a sample of individuals from all types of crashes, independent of where the crash occurred and whether health care was received (35-37). However, because NASS is a probability sample of all police-reported crashes in the United States and includes everything from truck- to motorcycle- to automobile crashes, children are underrepresented in the database, limiting its utility. For example, the emerging issue of child air bag-related mortality was not identified through NASS due to the relatively small number of children represented. The small sample size of children in NASS results in large sampling errors both with regard to determining the incidence of significant injury to children and the circumstances of any given type of crash (38). In addition, a significant limitation of studies utilizing NASS data is the reliance upon police reports of injury, which have been documented to be unreliable, particularly for children (39).

Both hospital-based studies and research using large existing databases utilize crash investigations as a methodological tool. During a crash investigation, investigation teams are dispatched to the scene to measure and document the crash environment, damage to the vehicles involved, and occupant contact points according to a standardized protocol. The on-scene investigations are supplemented by information from witnesses, crash victims, physicians, hospital records, police reports, and emergency medical service personnel. From this information, a report is generated that includes estimates of the vehicle dynamics and occupant kinematics during the crash and detailed descriptions of the injuries sustained in the crash by body region, type of injury, and severity of injury. Although these investigations provide detailed information regarding injury mechanisms and occupant kinematics, because of the limitations discussed above, the global context of these studies is unclear. Often these investigations do not include adequate control groups and the source population of the chosen cases is not known. Consequently, it is not known whether the results are representative of the underlying population of children in motor vehicles.

In summary, child-specific transportation safety research has been conducted, and has resulted in a significant decrease in motor vehicle-related mortality to children over the past 20 years (21). However, more recently, progress has slowed (40, 41), due in part to the more complex nature of modern child occupant protection problems such as misuse of child safety seats, side impact protection, and air bag-restraint system interactions. As a result, conflicting masses of information are given to parents, child restraint devices are often recalled, and public-policy decisions are based on tragic anecdotes of injured children rather than on sound, generalizable data.

The Child Occupant Protection Surveillance System is designed to build on the foundation of child-specific automotive safety research that has been conducted to date, and to address current gaps in our knowledge. This surveillance system provides the infrastructure to identify and conduct individual focused research studies or "targeted issues" that utilize telephone interviews and crash investigations as the research method. The unique combination of the surveillance system with the focused investigations provides a global context that combines epidemiological and engineering analyses using accepted methodology from each field.

METHODOLOGY

Overview

The research approach of "Biomechanical Epidemiology" was applied to the development of the surveillance system. In this approach, bioengineers, clinicians, epidemiologists, health educators, medical information systems specialists, professional crash investigators, and others developed a partnership with experts in insurance industry data collection for the inception, design, and implementation of the system. By integrating the expertise of multiple disciplines from the

outset, the final results will be useful to the widest possible audience. An Advisory Board of experts from multiple disciplines was created to provide guidance to the partnership.

The surveillance system involves identification of a census of children involved in crashes reported to State Farm Insurance Company. After consent is obtained by the claims representatives, a minimal dataset of information about these crashes, including contact information, crash location, driveable status of the vehicle, an initial description of the damage to the vehicle, the Vehicle Identification Number, and the age and treatment status of all child occupants, is obtained from the initial claimant. Following quality assurance review of the data at State Farm, the data is electronically transferred on a daily basis to the Children's Hospital/University of Pennsylvania Research team (the Research Team).

From this population, a representative sample of children with minor to severe injuries, in all types of crashes, from minimal to extensive vehicle damage, will be chosen according to a stratified sampling strategy. Contact information on the selected study sample will be electronically transferred to a telephone interview service. Drivers and parents of selected children will then be interviewed regarding the circumstances surrounding the crash and the nature and severity of the child's injuries. Completed interviews, devoid of personal identifiers, will be transferred back to the Research Team for analysis.

This surveillance system will provide a mechanism for the prompt identification of important "targeted issues" that require more detailed investigation and analysis. These targeted issue studies will utilize information obtained from the telephone surveys and crash investigations to learn more details about crash circumstances, occupant kinematics, and restraint system performance. These cases will be selected and analyzed using traditional epidemiological methodologies such as cohort studies in which cases will be chosen based on the presence or absence of a particular crash or vehicle characteristic and case control studies in which children with no significant injury will be paired with children with significant injury.

Study Population

All children between the ages of 0 and 15 years, riding as occupants (non-drivers) in crashes reported to the State Farm Insurance Companies from 15 states and the District of Columbia will comprise the population eligible for inclusion into the surveillance system. Only crashes involving model year 1990 and newer vehicles will be included in order to focus on state-of-the-art vehicle safety design features and to make results of the project applicable to the most relevant fleet. It is estimated that approximately 50,000 children per year are riding as occupants in eligible crashes reported to State Farm. Data collection will run for approximately 3 years for a total number of telephone interviews with the parents of approximately 20,000 children. From these interviews, approximately 600 crashes will be selected for targeted issue crash investigation analysis.

State Farm is the largest automobile insurance carrier in the United States, with over 35 million insured vehicles and 2 million crash claims annually. The regions of study chosen (East, Upper Midwest, West) represent 50% of the claims received by State Farm annually and a mixture of urban and rural populations and tort and no-fault states. The study was limited to these areas to minimize the number of State Farm personnel necessary to conduct the study and to centralize the locations of crash investigation teams.

Identification of Children in Crashes

The surveillance system will be initiated by insurance claims representatives through the systematic identification of children who were occupants in crashes reported to State Farm. The claims representatives function as initial field data collectors and obtain consent to release information to the Research Team about the child and the crash as part of the normal claims investigation process. In order to enhance the data collection and interpretation, information will be stored in the electronic claim file using objective measures. On a daily basis, a minimal dataset regarding the child and the crash is electronically transferred to the Research Team typically within 24 hours of the crash. For those crashes in which consent is not granted to release the information, State Farm keeps summary information.

Sampling Scheme for Surveillance System

For the cases that are transferred to The Children's Hospital of Philadelphia, a two-stage cluster sampling technique is used in order to efficiently identify the greatest number of injured children from among a representative population of crashes of all severities. In the first stage of sampling, each crash (i.e., vehicle) is assigned a value that corresponds to the worst treatment status of any child occupant. In this manner, crashes are stratified into four groups representing those crashes in which no child occupant received treatment, crashes in which at least one child occupant received outpatient/ emergency department treatment, crashes in which at least one child was admitted to the hospital, and crashes in which one child died. Once crashes are clustered this way, a random sample of crashes from each cluster is selected in order to ensure adequate representation of crashes of all severities. All child occupants from selected crashes are included in the final study population. Sampling weights are assigned to each cluster to ensure

inclusion of a broad range of crash severity as well as increase the proportion of child occupants in the final study sample that have a significant (AIS $\geq$2) injury. For example, a 100% sample of crashes in which at least one child was admitted to the hospital or died, a very small sample (e.g., 2%) of crashes in which no child occupant sought treatment, and an intermediate proportion (e.g., 50% sample) of crashes in which a child sought emergency department and/ or physician's office treatment will be selected.

The second stage of sampling is applied only to crashes that were assigned to the emergency department/ outpatient stratum in the first stage. Cases selected from this stratum undergo a brief screening telephone interview designed to rapidly identify those cases in which at least one child occupant suffered a significant (AIS $\geq$ 2) injury. All cases that screen positive for such an injury immediately proceed to a full interview on all child occupants described below. Contacts that screen negative are subject to random sampling to identify a small number that proceed to full interviews. The final surveillance system population is expected to consist of approximately 15,000 children with ten percent of the population < 1 year, thirty percent 1-4years, forty percent 5-9 years, and twenty percent 10-15 years of age.

Telephone Interview Tool Development

Cases selected for study have a minimum of data electronically transferred to Response Analysis, Co., a professional telephone survey company, for completion of an *Injury and Crash Circumstance Survey Tool* that was developed by the Research Team in conjunction with State Farm. The process of survey development included writing of interview scripts, pilot testing, evaluation of pilot interview results, and revision of scripts.

The survey has been designed to last approximately 25 minutes and ascertains information on the crash circumstances; driver behavior; trip circumstances; characteristics of restraint system used; size, weight and position of the occupant (exposures of interest); as well as the nature and severity of injuries to each child occupant (outcomes of interest). The injury outcome portion of the survey tool has been designed to allow classification of the body region, nature, and severity of injuries according to the Abbreviated Injury Scale (AIS) score. This portion of the survey has undergone validation in a pilot study conducted on injured children evaluated in the Emergency Department at The Children's Hospital of Philadelphia. Responses given by parents regarding the nature and severity of injuries were compared to information documented in the medical record. Throughout the period of data collection for the project, the circumstance portion of the survey will be validated by comparing information on the circumstances of the crash given by the driver with evidence gathered during on-site crash investigations.

Targeted Issues Studies

The surveillance system provides a mechanism for the prompt identification of key issues for which further research and study are needed to answer critical questions related to child occupant protection. Two methodological approaches will be utilized to address these "targeted issue" studies.

One method of addressing "targeted issue" studies is through the use of the crash investigations conducted by Dynamic Science, Inc. This method of data collection is used to address those study questions that require verification of interview data and more detailed information about the crash circumstances, occupant kinematics, and performance of restraint systems than is available through the surveillance system.

Whenever possible, cases selected for crash investigation-based targeted issues are chosen using two traditional epidemiological methods in order to provide a scientifically sound framework for the interpretation of data. One study design is the case-control study in which investigations will be selected based on whether a crash resulted in significant occupant injury (cases), or no child occupant injuries (controls). This type of design is particularly well suited for the efficient examination of a number of potential risk factors for significant injury. For example, to identify the independent contribution of several restraint characteristics, vehicle characteristics, and child characteristics to risk of significant injuries for the 6 to 9 year old population, a case control study design would choose crashes in which a 6 to 9 year old was injured (cases) and crashes of a similar nature in which a 6 to 9 year old was not injured (controls).

Another study design that is employed for crash investigation-based targeted issues is the cohort study. In this study design, crashes are selected for investigation based on the presence or absence of a particular characteristic, typically of the vehicle or crash. For example, to identify the effect of side impact protection on the severity of injuries to children, the cohort of cases is all side impact crashes. Crashes are then classified into two groups based on the exposure of interest, the presence or absence of side impact protection on the case vehicle. Investigations compare the nature and severity of injuries to children in vehicles with and without the exposure of interest. In most cases, the exposure parameter is a variable received from State Farm in the initial transmission of data to ensure the timeliness of the crash investigation.

The second methodology for the targeted issue studies is an in depth telephone survey to enhance the data collected in the surveillance system described above. These surveys would occur following the initial

surveillance systems survey. Examples of these directed telephone targeted issues include parental risk assessment, trip characteristics, and parental decision making.

In summary, the surveillance system and these two targeted issue methodologies will be conducted concurrently. Approximately 600 in-depth crash investigations will be conducted and an appropriate sample size from the 20,000 telephone interviews will be chosen for each targeted telephone survey. This unique combination of epidemiological and engineering methodologies will ensure high quality and comprehensive data on both crash circumstances and injuries to child occupants.

CONCLUSION

A motor vehicle crash surveillance system that focuses exclusively on children has been created and will address many of the limitations of current child occupant injury databases. The surveillance system consists of a probability sample of children from 0-15 years of age identified from all motor vehicle collisions reported to State Farm claims representatives in 15 states and the District of Columbia. The surveillance system using telephone interviews with involved drivers and parents of children provides the global context for individual focused "targeted issues". These specific research studies use crash investigations and directed telephone interviews. By performing these investigations within the framework of sound epidemiological studies, the results will be representative of the underlying source population of children in motor vehicle crashes. This study combines an insurer's capability to identify large numbers of motor vehicle collisions of research interest with timely investigation by an academic research team resulting in a research infrastructure designed to address current and emerging challenges in child occupant protection.

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