

Identifying Field Crash Data Collection Needs for a Pedestrian Crash Avoidance and Crashworthiness Study

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ABSTRACT

While pedestrian traffic fatalities have increased by over 25% in the past decade, there is currently a lack of detailed real-world vehicle-to-pedestrian crash data available for late model vehicles in the United States conducive to crash and injury causation analysis. The Crash Injury Research and Engineering Network (CIREN) Pedestrian Crash Pilot Study, running from 2018 to 2020 at two CIREN enrolling centers, will apply the CIREN investigation and analysis methods to collect detailed data on nine pedestrian crashes. The pilot study will develop updated pedestrian crash investigation, data collection, and injury causation analysis protocols to support both pedestrian crashworthiness and crash avoidance research and design.

Additionally, the CIREN pilot will consider the scalability of the protocols to a wider, future study. The inclusion criteria for the study require that the striking vehicle is a 2004 or newer model year, has original equipment manufacturer (OEM) components and no overlapping damage, is moving forward at the time of impact, and contacts the pedestrian forward of the A-pillar. The pedestrian must sustain AIS2+ injuries, and cannot be sitting, lying, or using a non-motorist conveyance (bicycles, skateboards, scooters) at the time of impact. Data collection will include elements related to the striking vehicle, pedestrian, scene/traffic-way, and medical records. Two investigation response protocols will be evaluated: fast response on scene and consent first then investigate. The CIREN pedestrian pilot will also evaluate new documentation technologies, incorporating 3D laser scanners and photogrammetric processing to produce point cloud data of the scenes and vehicles. Injury causation analysis will be performed utilizing the CIREN BioTab process updated for pedestrian crashes.

INTRODUCTION

In the decade between 2007 and 2016, overall pedestrian traffic fatalities increased by 27% (Traffic Safety Facts, 2016). Accompanied by a reduction in motor vehicle occupant fatalities, pedestrian crash fatalities as a percentage of overall traffic fatalities increased from 11% in 2007 to 16% in 2016. Serious injuries and fatalities resulting from vehicle-to-pedestrian crashes is a growing concern; however, detailed real-world data of pedestrian crashes with late model vehicles in the United States that can be used for crash or injury causation analysis is currently limited. The last pedestrian crash study of significance performed by the National Highway Traffic Safety Administration (NHTSA) was the Pedestrian Crash Data Study (PCDS), which ran from 1994-1998 and collected 521 cases (Chidester, 2001). Between 2007 and 2016, pedestrian fatalities from crashes with sport utility vehicles (SUVs) increased 54% compared to 27% for passenger cars. As vehicle front-end designs and the overall composition of the fleet have changed in the 20 years since PCDS was completed, there is a need for up-to-date vehicle-to-pedestrian crash data to address the future of pedestrian crashworthiness and crash avoidance.

The Crash Injury Research and Engineering Network (CIREN) is a field-based data collection and research program led by the Human Injury Research Division of NHTSA. Integrating clinicians and engineers to comprehensively study injury causation in motor vehicle crashes, CIREN's mission is to improve the prevention, treatment, and rehabilitation of motor vehicle crash injuries to reduce deaths, disabilities, and human and economic costs. The CIREN process combines prospective data collection with professional multi-disciplinary analysis of medical and engineering evidence to determine injury causation in every crash investigation conducted. CIREN utilizes a method called BioTab to identify and document the factors that led to a specific injury for the case occupant (Schneider, 2011). In BioTab, an injury causation scenario (ICS) is developed for each specific injury by assigning the source of energy (SOE) that led to the occupant loading that caused the injury, the involved physical components (IPC) that contacted the occupant, the path by which force was transmitted from the body region contacted to the site of injury, the injury mechanism at the body region level, contributing factors affecting injury likelihood or severity, and evidence supporting the choice of IPC and overall ICS.

Beginning in 2018, the CIREN Pedestrian Crash Pilot Study was implemented to expand CIREN investigations and analyses to include pedestrian crashes with late model vehicles in the US. Over the course of the two-year study, the pilot will develop updated pedestrian crash investigation, data collection, and injury causation analysis protocols that are relevant to current and future needs. Additionally, the CIREN pilot will consider the scalability of the protocols to a wider, future study. The CIREN pedestrian study applies the general methodology developed for CIREN occupant cases to vehicle-to-pedestrian crashes. The emphasis remains on identifying pedestrian injury causation and providing valuable data that may assist vehicle designers in reducing the aggressiveness of vehicle front ends to vulnerable road users. With the advent of pedestrian crash avoidance technology, the CIREN pedestrian study will also examine pre-crash circumstances of vehicle-to-pedestrian crashes. CIREN pedestrian cases will be available to validate computer models of vehicle to pedestrian interactions, and provide real-world scenarios for crash avoidance simulations. The initial protocols for the CIREN pedestrian pilot were developed from the methodologies utilized in PCDS, a previous CIREN pedestrian study conducted at the Inova Fairfax CIREN center from 2002 to 2007 that collected 67 cases (Longhitano, 2005), and the Special Crash Investigations Crash Avoidance and Mitigation Study performed in 2015 that collected 46 pedestrian cases. Advancements to the BioTab (injury causation coding) process will be incorporated and updated for compatibility with pedestrian cases.

METHODS

Study Details

There are two participating trauma centers where cases will be enrolled during the pilot study: Wake Forest Baptist Medical Center (Winston-Salem, NC) and Grady Memorial Hospital (Atlanta, GA). Engineering support will be provided by personnel at Virginia Tech-Wake Forest University Center for Injury Biomechanics, Emory University Department of Emergency Medicine, and the Medical College of Wisconsin

Department of Neurosurgery. The study began in 2018 and will run through 2020, with the collection and analysis of nine real-world vehicle-to-pedestrian crashes.

Inclusion Criteria

A pedestrian is defined as any person who is on a traffic-way or on a sidewalk or path contiguous with a traffic-way, or on private property (e.g., parking lot). This definition can include persons who are in contact with the ground, roadway, etc. and are pushing carts, wagons, etc., but will exclude the use of non-motorist conveyances such as bicycles, skateboards, wheelchairs, roller skates/blades, animals, etc. The inclusion criteria for injured pedestrians in crashes with motor vehicles are based on crash type, pedestrian attitude at impact, vehicle type, vehicle age, and occupant injury severity. The criteria for pedestrian crashes do not depend on pedestrian age, where there is no restriction. All pedestrian crashes must meet the following inclusion criteria to be eligible:

- The pedestrian is struck by a vehicle that is moving forward. Back-over cases are excluded.
- The pedestrian is not lying or sitting at the time of contact.
- The first point of contact between the vehicle and the pedestrian is forward of the top of the A-pillar.
- Only Crash Investigation Sampling System (CISS)-applicable motor vehicles (passenger cars, light trucks, SUVs, and vans as defined in the NHTSA Field Crash Investigations Coding & Editing Manual) are eligible.
- Vehicle model year of 2004 and newer (MY2004+).
- The striking portion of the vehicle structure must be original equipment manufacturer (OEM) without previous damage and or parts removed in the impact area. Vehicles equipped with deer guards, winches, snow plows, etc., or previously damaged in the impact area are excluded.
- The pedestrian impact(s) are the vehicle's only impacts. If multiple pedestrians are impacted, each pedestrian shall be a separate case.
- Injured pedestrians have at least one injury to their musculoskeletal system or brain that is classified with a severity of 2 or higher on the Abbreviated Injury Scale (AIS).
- Other non-motorist road users (bicycles, skateboards, scooters) will not be included at this time.

The CIREN program is focused on injury causation in crashes of newer vehicles, and has typically based its inclusion criteria on the model year of the case vehicle being a maximum of six or fewer years older than the calendar year at the time of enrollment. However, for the CIREN pedestrian pilot study, vehicles with model year 2004 and newer will be included to expand the pool of eligible cases and fill in the gaps in pedestrian data since the previous CIREN pedestrian study in the mid-2000s.

Crash Response Protocol

Pedestrian crashes present unique investigation challenges due to the time-sensitive nature of vehicle and scene evidence. To provide the most accurate data, certain case data elements must be documented on-scene, near the time of the crash. Case identification in CIREN normally begins once a case subject has entered the enrolling center and can be consented by study personnel (Consent First Investigate Later, CFIL), but the CFIL approach may inhibit the acquisition of timely and reliable scene and vehicle evidence for pedestrian crashes. Access to the involved vehicle becomes increasingly difficult once the vehicle leaves the scene.

For the CIREN pedestrian pilot study, a different approach to case identification may be required whereby potential cases are identified via emergency response dispatches. An investigator would receive the notification and then respond to the scene to begin data collection. This approach, termed Fast Response On-Scene (FROS), requires strong relationships with local law enforcement and EMS as well as the ability to send an investigator to the scene to begin data collection. This approach does not, however, guarantee that the struck pedestrian would be transported to the enrolling CIREN center and therefore may present problems with medical data acquisition. The CIREN pedestrian pilot study will incorporate both CFIL and FROS-style investigations to evaluate the feasibility and quality of case data acquired with each approach.

Data Collection Elements Overview

The data collection elements included in the CIREN pedestrian pilot study are divided into four main categories: Vehicle, Pedestrian, Scene/Traffic-way, and Medical. An overview of the data elements contained in each category is presented in the sub-sections below. The crash investigator will perform a scene and vehicle inspection to document the physical evidence. The pedestrian, driver of the striking vehicle, and witnesses will be interviewed to record their recollection of the crash event. The medical enrolling center will provide the detailed medical records of the pedestrian. The following paragraphs describe the types of data that will be collected for each category.

Vehicle. The geometry of the vehicle's striking plane including the heights, angles, and wrap distances of the major components (bumper, hood, windshield, A-pillar); vehicle component, location, crush damage, and underlying structures for pedestrian contacts with the vehicle; vehicle pre-crash speed, location, and intended path of travel; driver's line of sight to the pedestrian and available detection distance; vehicle speed at impact and distance travelled to the point of final rest; driver avoidance maneuvers and vehicle dynamics during the crash envelope; event data recorder (EDR) data related to the crash; availability and activation of any active safety systems.

Pedestrian. The pedestrian's pre-crash location, direction of travel, speed, and posture; any avoidance actions taken by the pedestrian; pedestrian's body orientation and phase of gait at the time of impact with the vehicle; kinematic trajectory of the pedestrian's interaction with the vehicle such as wrap, vault, or projection; secondary interactions with the roadway and ground; pedestrian's final rest location and throw distance from impact; type, reflectivity, and evidence of contact of the clothing worn by the pedestrian; the presence of any additional pedestrians and size of group.

Scene/Traffic-way. The location of the impact in the traffic-way, relative distances to intersections, crosswalks, and curbs; traffic signals, signage, and available pedestrian facilities; weather conditions, lighting conditions and vision obstruction for the driver and pedestrian.

Medical. The anthropometry of the pedestrian including knee, hip, shoulder, and overall height; medical and radiological data collected by the enrolling center including documentation of external injuries on the pedestrian, imaging of internal and skeletal injuries, admission and procedure reports.

Injury Causation Analysis

Injury causation analysis will be performed by the engineering centers and codified per the BioTab framework modified to account for vehicle-to-pedestrian interactions. The BioTab attributes list for pedestrian contacts (IPCs) will include a detailed breakdown of external vehicle components and environmental objects. Additionally, the available attributes for contributing factors, IPC evidence, and ICS evidence will be updated.

A new module defining the kinematic trajectory will be added to the BioTab process for pedestrian cases to account for the greater variability in struck pedestrian kinematics compared to vehicle occupants. The overall kinematic trajectory of the pedestrian's interaction with the striking vehicle and environment will be categorized into the five most common: wrap, forward projection, fender vault, roof vault, somersault (Ravani, 1981). The series of contacts between the pedestrian and the vehicle/environment will be discretized into a new parameter called "pedestrian conflicts." These conflicts, groups of contacts to a similar location that occur at a similar time, will allow for the different phases of the pedestrian trajectory to be isolated. Conflicts with components on the striking vehicle will be grouped into six vehicle planes (front, top, right side, left side, rear, and undercarriage), with a separate category for conflicts with objects in the environment. The overall kinematic trajectory will be composed of a sequence of pedestrian conflicts arranged in chronological order. For example, a typical wrap sequence would be initiated by a conflict with the front plane of the vehicle as the bumper/grille/hood leading edge strike the pedestrian, followed by a conflict with the top plane as the pedestrian wraps and contacts the top of the hood/cowl/windshield, and then a possible third conflict with the environment if the pedestrian slides off the hood and strikes the ground.

Scene and Vehicle Documentation

In addition to conventional scene and vehicle inspection protocols used in prior studies, the CIREN pedestrian pilot study will implement and evaluate the deployment of several new documentation strategies for the vehicle and crash scene. Point cloud data will be collected through two approaches: three-dimensional (3D) laser scanners and photogrammetric processing of images. Both technologies provide a time-efficient method to capture and preserve the frangible on-scene and vehicle evidence in the form of 3D point cloud data. The point cloud data will allow for detailed measurements to be taken virtually after the initial investigation is complete. Additionally, perspective views and fly-throughs from the point-of-view of the driver and pedestrian can be created to aid in crash avoidance investigations. Drone photography will be examined as a method to quickly document crash scenes.

Direct cooperation with local police traffic units has been established to allow for CIREN investigator access to closed crash scenes and the sharing of police collected data. Any available video footage of the crash or subsequent on-scene activity from intersection, private business, and police body cameras will be reviewed and analyzed when possible.

Special Considerations

As vehicle-to-pedestrian crashes during dark lighting conditions comprise a majority of pedestrian fatalities (about 75% in 2016), developing investigation protocols that are effective in low-light conditions and occur outside of normal working hours will be a focus of the CIREN pilot study. Crashes that occur during rapidly changing light conditions, such as dawn and dusk, present additional difficulty in documenting the environmental conditions at the time of the crash. Investigations of fatal crashes will require working without a pedestrian interview and potentially less detailed medical documentation of injuries sustained. The CIREN pedestrian pilot will ensure that low-light and fatal crashes are included in the nine cases collected.

Challenges and Limitations

There are several challenges anticipated in the collection of vehicle-to-pedestrian data. The CIREN program requires consent from the involved parties to be included in the study. The enrolling trauma center requires the consent of the struck pedestrian for access to the medical records and injury documentation. The crash investigators require the consent of local police to investigate scenes with the FROS approach, and will need the consent of the driver to inspect the striking vehicle. Additionally, there is increased uncertainty in the accident reconstruction and injury causation analyses of vehicle-to-pedestrian crashes as opposed to traditional CIREN occupant cases that must be considered. Finally, CIREN is a purposive sample that is not statistically representative, so there remains a need for pedestrian exposure data from other sources.

CONCLUSIONS

The CIREN Pedestrian Crash Pilot Study will collect detailed data on nine vehicle-to-pedestrian crashes at two CIREN enrolling centers from 2018-2020. The pilot study will develop updated pedestrian crash investigation, data collection, and injury causation analysis protocols. Two investigative response methods and new scene documentation technologies will be assessed to evaluate the quality of data achievable with each approach. Injury causation analysis will be performed following the CIREN BioTab protocol. Crash investigation data collection will include parameters relevant to pedestrian crash avoidance systems. The CIREN pilot will consider the scalability of the protocols to a wider future study.

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