Ambulance crashworthiness and occupant dynamics in vehicle-to-vehicle crash tests: Preliminary report

Session 5. Improved Safety for Vulnerable Road Users
(Bicyclists, Pedestrians, Children)
Session Chair: Yoshiyuki Mizuno

Paper # 452

Authors:
Nadine Robyn Levick, United States, Columbia University
Bruce Richard Donnelly, United States, Center for Transportation Injury Research
Alan Blatt, United States, Center for Transportation Injury Research
George Gillespie, Crew Systems, Naval Air Warfare Center, Patuxent River
Mike Schultze, Crew Systems, Naval Air Warfare Center, Patuxent River

ABSTRACT

There are no dynamic safety testing standards specifically for ambulance vehicles in the USA. These vehicles have also been identified to have high crash injury and fatality rates per mile, with a majority of the fatalities involving either an intersection or a frontal crash. This study is an interim report on work in progress which demonstrates occupant safety and crashworthiness of ambulance vehicles in vehicle to vehicle intersection type crash tests. The ambulance vehicles were configured with instrumented ATDs to represent 95th percentile male, 5th percentile female and 3 year child occupants. A ‘real world’ configuration of these ATDs and some medical equipment was established for a frontal and side impact crash test. The findings demonstrated life threatening safety hazards for all occupants. Also measured crash pulses for both the vehicle and the interior components were obtained. The urgent need for improvements to ambulance crash safety standards and designs are discussed.

INTRODUCTION

The ambulance transport environment is a vehicle passenger environment for which there are no specific occupant safety performance standards in the USA. This is also a high risk vehicle exposed to a high crash injury and fatality rate per mile traveled. Although there are safety standards being developed internationally, there has been very limited automotive safety research conducted addressing the occupant safety of these vehicles. Little is known about the forces, impact mechanics and occupant kinematics of the rear patient compartment of these vehicles under crash conditions. There exists no data based crash test pulses for the rear patient compartment of ambulance vehicles. There are no data based crash test pulses for the components of this environment such as the occupant restraint systems for the gurney, bench seat or rear facing seat. Furthermore there are no data to address the equipment restraint requirements for these vehicles. The objectives of
this study were to conduct and analyze crash tests of ambulance vehicles under real world

crash circumstances and to measure the crash dynamics of the vehicle and its occupants.

**MAIN TEXT**

In order to analyze increasing concerns associated with the crash safety of ambulances,
two 90° vehicle-to-vehicle crash tests typical of intersection accidents were performed to

assess the kinematics and mechanics of anthropomorphic test dummies (ATD) and the

crashworthiness of the patient compartment of ambulance vehicles.

**METHODS**

Preliminary data were collected to ascertain occupant size and location and types of

diagnostic equipment in the rear patient compartment of the ambulance vehicle. Based on

these prior studies, four ambulances were configured with crash test dummies and medical equipment. Type I, II and III vehicles were crash tested in two separate

intersection crashes. Occupants included four instrumented Anthropomorphic Test

Devices (ATDs) in the subject vehicle. Occupants were restrained in variable

configurations modeling real world situations and were exposed to both head on and side

impact scenarios. Some typical medical equipment was positioned in the rear cabin

patient compartment.

In the vehicle-to-vehicle crash tests conducted, the four instrumented ATDs were

positioned first in the target and then subsequently in the bullet vehicle. The ATDs

included a 3 year old child ATD which was restrained in a standard child restraint seat

(CRS) attached to the stretcher with belt restraints - and three adult crash dummies; a

50th percentile Hybrid II male ATD; a 95th percentile Hybrid II male ATD; and a 5th

percentile Hybrid II female ATD, which were seated in the patient care area in designated

seating positions as per the information from the preliminary data collection. Two ATDs

were positioned on the squad bench, an ATD on the rear facing captains chair, as well as

the child ATD on the stretcher in a CRS. ATDs were instrumented in the head and chest

with triaxial accelerometers. The vehicles were instrumented with redundant triaxial

accelerometers. High-speed film, documentary video and still photographs were also

obtained.

The restraint conditions for the adult ATDs varied in the two tests. The ATD in the rear

crash was restrained in each test, and only one adult ATD was unrestrained in any

test. In the first test the forward occupant of the bench seat was unrestrained, and in the

second test the rear occupant of the bench seat was unrestrained. The child ATD was

restrained as described above in both tests. All equipment in the rear patient compartment

was firmly secured, and with practices which were in excess of standard practices,

including ratchet belt systems and ‘duct tape’. This was due to concerns regarding

potential damage to either the ATDs or the photographic equipment as a result of possible

equipment projectiles. The first crash test was a stationary Type I (truck style)

ambulance struck at 90° on the right side forward of the mid point of the side of the

vehicle by a Type II (van style) ambulance vehicle. The instrumented ATDs in this test

were positioned in the Type I target vehicle. The second crash test was a Type III (large
truck style) ambulance striking a stationary Type II (van style) vehicle on the left side. The instrumented ATDs were positioned in the Type III bullet vehicle.

RESULTS
In both crash tests the target vehicle rolled onto its side after impact. The Type I ambulance, underwent a lateral change of velocity (deltaV) of 15 mph when struck at 90° by a Type II ambulance traveling at 46 mph. The Type III ambulance, traveling at 36 mph, underwent a deltaV of 18.5 mph after striking a Type II ambulance at 90°. In both tests, the child ATD kinematics and injury criteria demonstrated an effective technique for restraint. However unrestrained ATDs were a risk to both themselves and to other occupants. The restrained child ATD was exposed to a head and neck impact from an unrestrained 80 kilogram ATD. The proximity of the captain’s chair occupant to hostile interior surfaces resulted in severe head impact, with Head Injury Criterion indices of greater than 290 recorded. Effective equipment restraint was demonstrated using a ratchet belt locking system. Analysis of high speed films in the ambulance rear cabin revealed life threatening safety hazards associated with inadequate restraint systems and hazardous interior design and contact surfaces, despite the fact that vehicle impact accelerations were survivable and occupiable space was preserved. Unique data was also obtained and analyzed regarding impact acceleration characteristics for the vehicle, occupant seating stations, and occupant responses. These detailed electronic data are currently being processed.

CONCLUSIONS
The preliminary information from the crash closing speeds, high speed video and pre and post photographs highlight predictable and likely preventable injury mechanisms in the patient rear compartment. Hostile interior surfaces suggest a need to modify the ambulance interior, including optimization of the restraint systems and improved head protection for the occupants. There is an urgent need for improvements to ambulance crash safety and to develop performance based safety standards and safety designs.

ACKNOWLEDGMENTS

We a grateful to the staff at Veridian for their excellent technical support of crash tests. Additionally to the State of New York EMS Department for support and encouragement throughout this project and the Ambulance Association of America for assistance with availability of vehicles.

REFERENCES

4. National Highway traffic Safety Administration (NHTSA), Fatal Accident Reporting System (FARS), 1987-98
Figure 1. Vehicles post first crash test
Figure 2. Vehicle interior (target vehicle) post first crash test