

## 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*

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#### **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 90o 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 medical 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 facing chair 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 90o 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 90o 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 90o. 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.

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Figure1. Vehicles post first crash test



Figure 2. Vehicle interior (target vehicle) post first crash test

