



## **Ambulance vehicle crashworthiness and passive safety design – A comparative evaluation of Australian and USA design and testing standards**

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## **Objective**

- ▶ To evaluate crashworthiness and passive safety design and testing standards for USA and Australian ambulance vehicles

## **Ambulance vehicle definition**

- ▶ Emergency medical response and transport ground vehicle with stretcher carrying capabilities

## **Unique aspect of vehicle safety infrastructure**

- ▶ Ambulance retrofit - small market
- ▶ These are the very vehicles that are there to respond to passenger vehicle safety failures
- ▶ Important that testing requirements and standards be designed to address real world risks and hazards for occupants of these vehicles

## **Background historical snapshot**

- ▶ A unique 'passenger vehicle – workplace' and also emergency medical environment
- ▶ USA ambulance vehicle historically changed from intact automotive vehicle – the Cadillac, to truck or van cutaway chassis with non automotive engineered after market box, and few sporadic OEM van vehicles
- ▶ Australia similar history however since 2000, the majority of the fleet is OEM van vehicles

**USA**

**1960 to 2007**

**Australia**



1960's



1980's



2007



## Real world issues for safety testing of ambulances

- ▶ Occupants are oriented in a range of seating and lying positions
- ▶ Medics are trying to perform clinical and emergency care during transport (less than 5% life critical)
- ▶ Often heavy equipment in close proximity to occupants
- ▶ Unusual environment where occupant protection is impacted both by realms of vehicle and interior design AND also practice policy

## Background: Magnitude of the Problem

- ▶ **In USA**
  - Fleet ~ 50,000 ambulance transport vehicles
  - ~ 5,000 ambulance vehicle crashes/year\*\*
  - ~ One fatality each week\*
  - 82% of fatally injured EMS rear occupants were unrestrained\*\*
  - ~10 x as lethal per mile traveled than large trucks#.##
- ▶ **In Australia**
  - Fleet ~ 5,000 ambulance transport vehicles
  - Fatalities a very rare event < 1 per decade
  - USA ambulance crash fatality rate/capita 35x higher than in Australia

\*FARS/GIES BTS, 2000-2006  
 \*\*Maguire, Hunting, Smith, Levick, *Annals Emerg Med* Dec 2002  
 \*\*Becker, Zaloshnja, Levick, Li, Miller, *Acc Anal Prev* 2003  
 # Kahn CA, Pirrallo RG, Kahn EM, *Prehosp Emerg Care* 2001 Jul-Sep;5(3):261-9  
 ##FMCSA 2006

## Recent Australian press – however no supporting data...

### Paramedics say ambulances are unsafe

October 12, 2007 - 1:38PM

Melbourne paramedics say they have been ordered to use ambulances this weekend that they believe to be unsafe.

They say the Metropolitan Ambulance Service (MAS) has threatened them with \$6,000 fines unless they use the vehicles, which have exceeded their agreed service life of three years or 150,000km.

Ambulance Employees Australia (AEU) general secretary Steve McGhie says the vehicles need to be in perfect working order or they pose a risk to the public, patients and paramedics.

### Melbourne ambulances 'unsafe'

Reiko Fernie  
 October 12, 2007 - 3:36PM

Melbourne paramedics say they have been ordered to use ambulances this weekend that they believe to be unsafe.

They say the Metropolitan Ambulance Service (MAS) has threatened them with \$6,000 fines unless they use the vehicles, which have exceeded their agreed service life of three years or 150,000 kilometres.

## Some recent USA ambulance crash outcomes



## Ambulance Safety Research: A New Field



## Early Crash Testing

- ▶ Australia 1989 (Victoria Ambulance)



## Early Crash testing

- ▶ USA 2000 (Johns Hopkins research project)



## Using real world practice research model



## USA 2004, NIOSH Head strike zone hazards



## Methods

- ▶ Ambulance vehicles and safety testing standards and requirements were identified from the USA and Australia

## Methods

- ▶ A comparative evaluation of the applicable safety testing standards for ambulance vehicles was performed by a combined team of automotive safety engineering and emergency health expertise

## Methods

- ▶ The comparative evaluation of the safety of the design and testing of the vehicles was based on:
  - ♦ basic principles of crashworthiness and effective countermeasure development
  - ♦ information on the design and construction of the USA and Australian ambulance vehicles
  - ♦ crashworthiness testing conducted by the authors and other agencies of ambulance vehicles

## Methods

- ▶ Data sources include:
  - ♦ Testing/safety standards and specifications
  - ♦ Vehicle specifications
  - ♦ Inspections and photographs and crash testing conducted of ambulance vehicles
  - ♦ Established published literature on ambulance crashworthiness
  - ♦ Established published literature on automotive crashworthiness principles and impact mechanics

## Results

- ▶ Testing standards
- ▶ Occupant protection hazards and passive protection

## Specific design and safety testing standards

- ▶ Australia:
  - ♦ ASA AS/NZS 4535:1999
    - Ambulance Restraint Systems
  - ♦ Current from 1999
- ▶ USA:
  - ♦ GSA KKK-A-1822F
    - Federal Specifications for the Star-of-Life Ambulance
  - ♦ AMD/NTEA Ambulance Design Standards –
  - ♦ Both current from 2007

## Australia & New Zealand Ambulance restraint standard AS/NZS 4535:1999

- ▶ “Restraint systems shall apply to all equipment and people carried in an ambulance...”
- ▶ Dynamic Testing - 50th & 95th percentile manikins
- ▶ 24G in Forward and Rearward
- ▶ 10G in Transverse



## ASA Ambulance Restraint Standard

- ▶ Focused toward restraint of occupants and equipment
- ▶ Clearly specifies dynamic testing
- ▶ Nature of testing similar to forces in passenger vehicle restraint tests
- ▶ Addresses a range of ATD dimensions
- ▶ Developed with in the framework of accepted automotive safety engineering principles
- ▶ Does not require vehicle intrusion testing
- ▶ Is not regulated by any mandatory compliance requirement or law

## USA ambulance purchase specifications GSA:KKK-A-1822F, Aug 2007

- ▶ Static Pull test
- ▶ 2200 Lbs. (8G's) in Longitudinal and Lateral
- ▶ No dynamic test
- ▶ No definition to manikin mass
- ▶ No restraint for equipment
- ▶ Voluntary



## USA Specified Federal Motor Vehicle Safety Standards (FMVSS) exemptions for ambulances

- ▶ CFR49 Part 571
  - ♦ 571.214: Side impact - exempt
  - ♦ 571.201: Head impact protection - exempt 60 cms from drivers reference seating position
  - ♦ 571.208, S4.3.2 – Occupant Crash Protection: Frontal indirect exemption

## USA Ambulances: FMVSS Exempt

DEPARTMENT OF TRANSPORTATION  
National Highway Traffic Safety Administration

**49 CFR Parts 571, 572, and 589  
[Docket No. 92-28; Notice 7]  
[RIN No. 2127-AB85]**

**Federal Motor Vehicle Safety Standards:  
Head Impact Protection**

58.1 Vehicles manufactured on or after September 1, 1998 and before September 1, 2002. Except as provided in 58.3, for vehicles manufactured on or after September 1, 1998 and before September 1, 2002, a percentage of the manufacturer's production, as specified in 58.1.1, 58.1.2, 58.1.3, or 58.1.4, shall, when tested under the conditions of 58, comply with the requirements specified in 57 at the target locations specified in 57.0 when impacted by the free motion headform specified in 58.9 at any speed up to and including 24 kilometers per hour. The requirements do not apply to any target that cannot be located using the procedures of 57.9. The phase-in schedule the manufacturer chooses to use during this period shall be reported to the National Highway Traffic Safety Administration pursuant to 49 CFR 589.6.

58.2 Vehicles manufactured on or after September 1, 2002. Except as provided in 58.3, vehicles manufactured on or after September 1, 2002 shall, when tested under the conditions of 58, comply with the requirements specified in 57 at the target locations specified in 57.0 when impacted by the free motion headform specified in 58.9 at any speed up to and including 24 kilometers per hour. The requirements do not apply to any target that cannot be located using the procedures of 57.9.

58.3 A vehicle need not meet the requirements of 56.1 through 56.2 for:

- (A) Any target located on a convertible roof frame or a convertible roof linkage mechanism;
- (B) Any target located rearward of a vertical plane 600 mm behind the seating reference point of the rearmost designated seating position;
- (C) Any target located rearward of a vertical plane 600 mm behind the seating reference point of the driver's seating position in an ambulance or a motor home;
- (D) Any target in a walk-in van-type vehicles.

DOT/NHTSA, FMVSS 49 CFR Parts 571, 572 & 589 Docket no. 92-28; notice 7

## USA AMD STANDARD - 2007

- ▶ Static Tests (AMD STANDARD 001, 002, 003, 004, 008)
  - "...to reduce the possibility of injuries and fatalities that could result from the failure of the ambulance body structure that may be encountered in roll over crashes."
  - "...to minimize possibility of its failure by forces acting upon it as a result of vehicle crashes and/or sudden driving maneuvers"
- ▶ Occupant Head Clearance Zones AMD STANDARD 025
  - "The purpose of this standard is to insure that measurement of occupant space is done correctly.
  - S4 DEFINITIONS: S4.1 Head Room:  
The space above a designated seating area where no contactable surfaces are permitted. This area is to be free of any thing the head of the passenger might contact if an accident where to occur. *The walls are exempt from this requirement*"

## USA KKK Specification - 2007

- ▶ Specifies that a successful test is:
  - ♦ No structural damage to any load bearing or supporting members, i.e., torn or broken material, broken welds, popped or sheared body rivets, bolts, and/or fasteners, shall be evident during the application of the force and after the release of the force

## USA Occupant protection.....?? July 2007

Medic Survivors

Medic Fatality



## Current 2007 USA ambulance 'safety testing' practices !?? Unacceptable, and ridiculous...

**AMBULANCE TEST RECORD BROKEN**

<p><b>36,000 lbs</b></p>	<p><b>55,000 lbs on ROOF</b></p>	<p><b>55,000 lbs on SIDE</b></p>
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**THAT WAS THEN**      **THIS IS NOW...**

In 2000, shattered industry records by testing and certifying the modular body to more than double the 150% curb weight Federal Standard. In addition, they performed a body side test that had never been seen before. Now has broken that record with a 55,000 body test on the top and side of the module. The ambulance body is now certified to a 500% curb weight level! **•MORE INFO**

**INDUSTRY LEADING SAFETY INNOVATION**



No 'a'... then NO 'F' !!!!!

►  $F = ma$

where F – force  
m – mass  
a – acceleration

Occupant hazards and safety features

### Australia real world crash data

High speed crash, rolled and the occupants (patient and medics)  
only minor scratches



### Australian vehicles



### Australia – Forward and rear facing seating only



### USA Occupant Hazards





## Results

- ▶ Australian vehicles demonstrated safety enhancement approach for all occupants, as well as a focus on occupant human factors, and equipment location and anchors were identified
- ▶ Interior design features (i.e. seat design, and orientation, head strike zones, and restraint systems) and vehicle interior layout, were key areas of optimized safety design

## Results

- ▶ Several features identified for USA ambulance vehicles, which apparently met the KKK specifications - demonstrated predictable serious crashworthiness and occupant protection hazards
- ▶ No comment in KKK-F (or KKK-E) that the seat belts in the rear compartment must be secured to a structural part of the vehicle
- ▶ Even within the 60 cms it appears that USA ambulances are essentially non compliant in that crash testing studies of the safety performance of the captains chair and bulkhead are not performed

## Discussion

- ▶ An ambulance vehicle is a vehicle that carries passengers – not just freight, and safety standards should address the real safety of those passengers, and reflect accepted current automotive safety science and crash test procedures
- ▶ Real world injury data on ambulance crashes is at best limited – testing not driven by real world injury data and/or NCAP
- ▶ Ambulance vehicles that are not intact OEM vehicles, or are structurally modified cannot be effectively demonstrated to be safe for occupants in the rear compartment in the absence of full vehicle dynamic impact testing to demonstrate intrusion

## USA KKK/AMD

- ▶ Ignorant of automotive safety principles -
  - ◆ Makes no reference to dynamic testing and YET makes reference to this standard providing protection in the setting of vehicle crash forces
  - ◆ The complete ABSENCE of any real world injury data applied to the determination of these test protocols

## Discussion

- ▶ The USA KKK- F AMD 2007 test protocols are outdated and no longer accepted in automotive safety
- ▶ Such test protocols would provide misleading information that could not be supported by any current accepted automotive safety, occupant protection and crashworthiness science or any principles thereof
- ▶ Ambulance vehicles that are not intact OEM vehicles, or are structurally modified cannot be demonstrated to be safe for occupants in the rear compartment in the absence of full vehicle dynamic impact testing to demonstrate intrusion

## Seating orientation issues

- ▶ Side facing squad bench concerns
  - ♦ A challenge is the right hand side 'squad bench' – a structure that has minimal if any automotive safety features
  - ♦ Described in previous military vehicle crash testing to be a hazardous mode of occupant transport in a forward traveling vehicle (Richardson et al 1999, Zou et al 1999)
- ▶ Reference to preference of forward and rear facing seating positions was not evident in either USA or Australian standard

## Visibility and conspicuity issues

- ▶ The focus of this study was on crashworthiness and occupant protection however, integration of the science and data on visibility and conspicuity was regarded by the authors as an important aspect of safety
- ▶ Australian fleets did strongly focus on this aspect regardless of it not being encompassed by these standards

## Limitations

- ▶ The serious limitation of absent real world injury and crash data for guiding design and testing profile development and evaluation
- ▶ Lack of a national perspective on transportation data capture for system performance, magnitude and safety issues
- ▶ Refinement of crash pulses to specifically meet these vehicle's design and performance has not taken place

## Conclusion

- ▶ In a setting of safety records with an order of magnitude difference in performance - there was also marked difference in the safety standards for Australian and USA ambulance vehicles
- ▶ Australian ambulance vehicles have safety features and testing requirements basically consistent with accepted crashworthiness principles
- ▶ USA ambulance vehicles have 'safety features' and testing requirements quite outside of any current accepted automotive safety engineering principles for occupant protection or crashworthiness and not supported by existing and accepted technical data
- ▶ There is need for safety researchers, emergency medical service providers and ambulance vehicle designers to recognize and apply existing crashworthiness principles to reduce current system failures, and importantly to develop comprehensive safety standards for ambulance vehicles that reflect real world transportation safety hazards

Thank you!  
Any Questions??



<http://www.objectivesafety.net>