**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**

- 1960’s
- 1980’s
- 2007

**Australia**

- 1960'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
- ~10x 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

Recent Australian press – however no supporting data...

Some recent USA ambulance crash outcomes

Ambulance Safety Research: A New Field

- Engineering
- Ergonomic
- Epidemiology

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:
  - 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 within 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

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**

- **49 CFR Parts 571, 572, and 576**
  - [Docket No. 92-28; Notice 7](https://www.federalregister.gov/documents/1992/05/07/92-28/notice-7)
  - **FMVSS Exempt**

**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 rollover 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 ensure 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
  - **THAT WAS THEN**
    - In 2000, shelled 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 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 150% curb weight level.
  - **THIS IS NOW**
No ‘a’… then NO ‘F’ !!!!!

\[ F = ma \]

where  
\( F \) – force  
\( m \) – mass  
\( a \) – acceleration

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 cannot 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??

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