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Ambulance vehicle crashworthiness and passive safety design: *A comparative evaluation*

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Introduction

- Major differences in the oversight and design standards for ambulance safety and occupant protection in USA compared to Australia.
- Since 1999 Australia has had an Australian Standards Association (ASA) approved ambulance standard
- USA has a specification (GSA KKK-F) and a 'standard' (AMD 2007) that address ambulance design – neither are from automotive standardizing bodies

Some odd USA facts

- 97% of ambulance transports are routine
- <3% are critical or life threatening
- Ambulances are generally not built by the automotive industry
- Rear occupant compartment high risk of serious injury and fatality
- The most lethal commercial vehicle on the road

Design and manufacturing approach - USA and Australia

- There is some variation within each country, however there are features more characteristic of ambulance design and manufacture specific to each country
- Additionally the system of oversight and design standards and the development of those standards differ quite dramatically between the USA and Australia

Ambulance Manufacture - USA

- Majority - after market rear occupant box (Type 1 & 3), built by non-automotive industry retrofitter, who also attaches the box to Original Equipment Manufacturer (OEM) chassis.
- Occupant safety aspects of such rear compartments are under the purview of that retrofitting industry
- Some van type vehicles (Type 2) for which aftermarket manufacturers remove and replace roof with a roof extension not fitted by the OEM of the vehicle, nor has this fitment been crash tested.

And….

- Increased marketing 'safety concept' ambulances in the USA
- An absence of independent automotive safety engineering technical evaluation of design and potential safety performance
- An absence of USA ambulance occupant protection and safety performance standards

Ambulance Manufacture - Australia

- In contrast to USA, the majority of the ambulance vehicles are automotive industry built vans (Type 2 style) – without structural alteration by the aftermarket retrofitters
- The standards involved are generated by standardizing bodies that address automotive and occupant protection standards in other settings

Objective

- To evaluate the potential safety performance and occupant protection of an Australian and 4 USA prototype 'safety concept' ambulances based on accepted crashworthiness performance principles

Methods

- This evaluation is a broad based engineering evaluation of basic and fundamental aspects of occupant protection, crashworthiness and safety design features
- This methodology was based on a validated engineering study methodology previously performed on ambulance and other vehicles

Methods

- 5 recently designed ambulance vehicles were identified and compared
- 4 from the USA and one from Australia
- Broad based evaluation of basic and fundamental aspects of crashworthiness
- Ambulance crashworthiness testing conducted by the authors and other agencies, and detailed information on the design and construction of the study vehicles

Ambulance Standards??

- Australia
  - ASA
- USA
  - KKK?
  - AMD?
  - FMVSS?

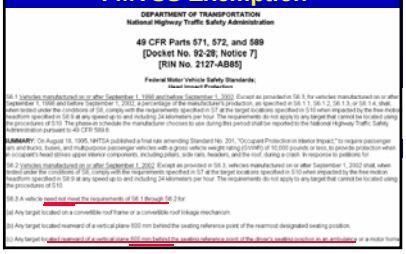
Australia & New Zealand Ambulance restraint standard AS/NZS 4535:1999

- "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

KKK and AMD Specifications and Standards

- The KKK-F specifications and the AMD Standard, reference and default on many safety issues to the Federal Motor Vehicle Safety Standards (FMVSS)
- However the FMVSS sections have specific exemptions for ambulance vehicles
- FMVSS exemptions apply to any occupant or structure located 600mm behind the seating reference point of the driver of the ambulance vehicle
- The AMD standards, developed internally by the AMD, make numerous references to FMVSS compliance even though the FMVSS have specific exemptions for ambulance vehicles

USA Ambulances: FMVSS Exemption



DEPARTMENT OF TRANSPORTATION
National Highway Traffic Safety Administration

49 CFR Parts 571, 572, and 589
[Docket No. 92-28; Notice 7]
[RIN No. 2127-AB80]

Federal Motor Vehicle Safety Standards;
Head Impact Protection

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

- Specifications for the purchase of a Star of Life Ambulance
- Static Pull test
- 2200 Lbs. static stretcher test in longitudinal, lateral & vertical
- No dynamic test for vehicle, occupants or equipment
- No automotive test manikin
- Voluntary www.ntea.com/WorkArea/downloadasset.aspx?id=1552

USA Ambulance Manufacturing Division (AMD) Ambulance Standards – August 2007

- No dynamic or impact test
- No automotive test manikin
- Mandates NO 'crumple zone'
- No impact tested anchorages for occupant restraint or equipment
- Internal, not independent

http://www.ntea.com/WorkArea/showcontent.aspx?id=1360

Unacceptable, and ridiculous current 2008 USA ambulance '*safety testing*' practices !!??

AMD 2007 - 025 'static occupant safety testing'

- Compared with -

Accepted automotive safety dynamic occupant testing

AMD – static 'safety testing'

- Inconsistent with automotive safety principles – and 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.

Occupant protection……?? July 2007

KKK certified and FMVSS exempt..?


2 dead in Michigan ambulance crash

The Associated Press

Patient and Provider occupant fatalities, June 2008…

the study vehicles

Study Vehicle – Australia (vehicle A)

- The Australian vehicle was a recent safety focused design retrofitted into an OEM vehicle
- Involved the automotive manufacturing and safety industry in its design and development – in addition to peer reviewed engineering and automotive safety literature
- There exists an automotive standard based on crash test principles to evaluate its safety

Study Vehicles - USA (vehicle B-E)

- USA vehicles self designated as "Safety Concept" ambulance vehicles by the manufacturers and purchasers
- No described or available technical literature or publications to support the effectiveness or performance of safety features or innovations
- Material that promoted the safety of the vehicles was primarily advertising material from the aftermarket retrofitter, or purchaser and general EMS magazines

Study Vehicles - USA (vehicles B-E)

- USA vehicles configured with an aftermarket box built outside of the automotive safety industry, attached to an automotive industry built chassis. For 3 a light truck was used and for one of the vehicles a heavy truck was used
- No evidence in peer reviewed technical literature demonstrate interior configurations and vehicle structures provide rear occupant protection and crashworthiness

Interior Vehicle A

Results Vehicles B-E

- Poor predicted crashworthiness for these aftermarket modified chassis and box design ambulance vehicles based on the based both on fundamental crashworthiness principles and available crash data
- Assessed crashworthiness performance and occupant protection do not appear optimized for these vehicles

Results Vehicles B-E

- Design failures of utilizing the non-crash tested occupant compartment aftermarket box construction design
- Side facing seating positions with the use of hazardous four or five point harnesses for seated occupants
- Comprehensive automotive and crashworthiness data identifying the serious hazards of this practice

NOT new technical data…

*Richardson S.A., et al, Int. J. of Crash., 4:3, 239 – 259, **1999***

Side facing 4-point harnesses demonstrated to be lethal, even at slow ground vehicle speeds

Results Vehicles B-E

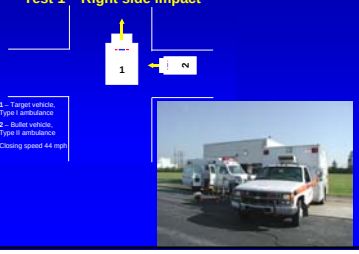
- Large area inside the vehicles promoted unsafe behaviors in a risky occupant environment, challenges in accessing patient or any necessary equipment
- Some design features that may mitigate risk to some degree – such as communications systems that did not require the occupant to be ambulant inside a moving vehicle to access radio communications. However the performance under crash circumstances of these systems is not known

Results Vehicles B-E

- As in the preliminary study, concerns raised regarding the nature of the attachment of the 'box' to the chassis and the potential for the rigidity of this system to increase the transfer of energy to the rear compartment occupants
- This was clearly demonstrated in some recent real world crash data, in addition to the crash testing conducted by the authors

Full Vehicle Crash Testing

Test 1 – Right side impact



USA Ambulance full vehicle crash test research data (SAE/ESV)

Vehicle interior on impact

NIOSH Ambulance Occupant Safety Crash Testing (not peer reviewed/published)

Impact Direction

25 MPH !

Results

- Further systems failure in the design of the USA vehicles
- A seating design that included a configuration in the sole rear facing seating position that could be modified to provide a small restraint system for use for a child.

Results

- Concerns for safety of a child in that design
  - Firstly, no lateral protection with serious head strike hazards in side or offset impact
  - Secondly, medical care hazards
    - Medical care access is not practical with a child seated in that manner, with their back against a wall
    - No safe way for an ambulance provider to provide medical care without putting both the child patient and the provider at risk
  - Thirdly, once a child was in that modified seating position, the provider would be forced to only other available seating positions, which were side facing

Side facing seating and 4 point harness hazards

Results

- These types of systems safety issues, where the positioning of one occupant limits the safety options for other occupants such as this, demonstrates that the interaction between occupants and their positioning can create for more hazards
- This appeared to be a repeated design failure aspect of the USA vehicles

Results

- Liberal use of netting in vehicles B, C, and E
  - Though no testing of the netting material or its performance under impact conditions, or its ability to mitigate injury, was referenced by any manufacturer
- Real world reports suggest netting attachments pull out under impact, and provide limited if any protection
- In studies conducted by the authors and others, concerns about the netting construction and anchorage, and potential serious head and neck hazards

Results

- Exemptions from OEM safety performance standards identified as problematic by the NTSB, back in 1979 - *"…there are no standards or specifications which assure that the total design and construction of ambulances as modified by the after-market installers are of sufficient structural strength and stability to withstand impact forces similar to requirements imposed on the original vehicle manufacturer... FMVSS... protection was not extended to the patients or medical personnel occupying the body of the ambulance since it did not apply to the modifications made after the vehicle was sold by the manufacturer."*
- Has been no remedy in the USA to address this to date

Results

- In contrast there was extensive demonstration of systems safety design and effective occupant protective features in the non-USA vehicle, Vehicle A
- This vehicle was built structurally by vehicle manufacturer OEM, and required to meet that manufacturers safety performance standards, with no aftermarket alterations to the vehicle structural design

High speed crash, rollover - occupants (patient and medics) only minor scratches

Results Vehicle A

- No market structural vehicle modifications that can potentially decrease OEM crashworthiness integrity
- Excellent examples of creative and innovative safety design in vehicle A
- Unlike vehicles B, C, D and E, no squad bench, no side facing seating positions and no four or five point harnesses in any such orientation

Results Vehicle A

- Only forward or rear facing seating, and design focused around minimum mobility of the EMT in the rear compartment.
- One feature was an equipment cabinet that could move from one EMT position to the other – minimizing the need for ambulating to access essential equipment
- There was also no cabinetry in the potential head strike zones

Discussion

- Whilst the science, practice and principles of automotive safety is a well advanced technical science and discipline, this study demonstrates a serious and substantive disconnect between what is known, well described and understood in the world of automotive safety technology and what appears to be occurring in the design and development of some ambulance vehicles, particularly in the USA

Discussion

- Of increasing concern is that the USA general EMS association publications and magazines continue to publish "reviews" of these "Safety Concept" vehicles in non technical EMS industry magazines, widely broadcast and distributed, yet absent of technical automotive safety engineering or crashworthiness input

Discussion

- These EMS publications espouse a perception of safety innovation that has no credible basis in either the open automotive safety literature or worlds best practice vehicle crashworthiness standards
- As a result of these EMS industry "review" articles - EMS personnel are now making design and purchase decisions which could be placing patients and EMS personnel at predictable risk of serious injury

Discussion

- For those not trained in automotive safety engineering and crashworthiness, and in the absence of standards, it is difficult to process this situation
- These USA "Safety Concept" vehicles are not vehicles that utilize state of the art occupant protection systems for the rear compartment and are not demonstrated to be crashworthy
- As such, they should not be considered by fleet purchasers as model safety vehicles.

Conclusion

- Features of ambulance design in 4 of 5 vehicles studied are potentially hazardous and not within the known principles and technical aspects of crashworthiness and automotive safety design, and demonstrated predictable serious crashworthiness and occupant protection hazards
- Non crashworthy rear compartment construction and potentially hazardous interior design features (ie. side facing squad bench and seat design, head strike zones, and inappropriate restraint systems)
- Interior layout was a key area for improvement as well as a clear focus on occupant human factors, and equipment location and anchors

Conclusion

- Need for safety researchers, automotive and transportation engineers, emergency medical service providers and ambulance vehicle designers to recognize and apply these existing principles of automotive safety, systems engineering and occupant protection, particularly to ambulances manufactured in the USA
- The failure to address the design of these USA vehicles based on accepted crashworthiness and occupant protection principles, published peer reviewed automotive safety literature and in isolation of the extensive global expertise in automotive safety and human factors, remains a serious concern

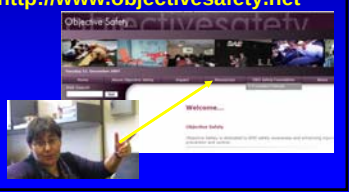
Thank you!

Any Questions??

Paper available at SAE store

Electronic handout available online

http://www.objectivesafety.net



The EMS Safety Foundation

Intro and Logistics Webinars from December 11th 2007 & Jan 8th 2008

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