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

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ABSTRACT

Objectives: To evaluate crashworthiness and passive safety design and testing standards for USA and Australian ambulance vehicles

Methods: Ambulance vehicles and safety testing requirements were identified from the USA and Australia. A comparative evaluation of the safety design standards for ambulance vehicles was performed. Data sources include: testing and safety standards and specifications, vehicle specifications, inspections and photographs and crash testing conducted of ambulance vehicles and established published literature on ambulance crashworthiness and crashworthiness principles.

Results: Design and safety testing requirements and standards for Australian ambulance vehicles were consistent with accepted engineering technical vehicle and occupant safety standards. However, for USA vehicles the testing standards and design requirements were not in keeping with accepted engineering technical vehicle and occupant safety standards with a number of highly misleading and potentially dangerous aspects to the standards and specifications and some practices that were well outside of anything that would be acceptable vehicle testing or design features - such as the use of static loads to demonstrate crashworthiness performance, and requirements which prevent the use of any crumple zones or impact absorbing structures. Several features identified, for the USA ambulance vehicles, demonstrated predictable serious crashworthiness and occupant protection hazards.

Conclusion: There is marked disparity in the vehicle crashworthiness and passive safety design and standards for ambulance vehicles in Australia and the USA - the USA ambulance design standards being outside of accepted automotive safety engineering practice. There is a need for safety researchers, emergency medical service providers and ambulance vehicle designers to recognize and apply existing crashworthiness principles to reduce current ambulance design system failures, and for safety testing standards to address the areas that will enhance the safety performance and occupant protection of ambulance vehicles. This is key and fundamental information for a major fleet of essential service vehicles globally which has had minimal automotive safety attention or input to date.

BACKGROUND

Ambulances in the USA are 35 times per capita more lethal than in Australia. Whilst there are many aspects that impact upon safety, this study addresses the safety design standards and guidelines for ambulances in the two countries. Ambulances in the USA are built by aftermarket ambulance manufacturers, to meet the Ambulance Manufacturing Division's (AMD) own design standards and the General Services Administrations KKK-F Star of Life Purchase Specification. These standards are essentially developed outside automotive safety and crashworthiness engineering oversight. Federal Motor Vehicle Safety Standard exemptions exist for the rear compartment occupants. Australian ambulances are required to meet the Australasian Standard AS/NZS 4535:1999 Ambulance Restraint Systems Standard for safety and occupant protection in ambulance vehicles. This is a national standard by an independent nationally approved standardizing agency.

OBJECTIVE

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

METHODS

Ambulance vehicles and safety testing requirements were identified from the USA and Australia. Based on crashworthiness testing conducted by the authors and other agencies of ambulance vehicles and basic principles of crashworthiness - a comparative evaluation of the safety of the design of the vehicles was performed. Data sources include: testing and safety standards and specifications and crash testing conducted of ambulance vehicles and established published literature on ambulance crashworthiness and crashworthiness principles.

RESULTS

Design and safety testing requirements and standards for Australian ambulance vehicles were consistent with accepted engineering technical vehicle and occupant safety standards, including dynamic impact testing procedures (Fig 1.). Additionally these standards also addressed a spectrum of occupant dimensions.

Fig. 1. Australasian Ambulance Safety Standard AS/NZS 4535:1999

APPENDIX C
CALIBRATION OF THE DYNAMIC TEST RIG
(Normative)

C1 SCOPE This Appendix sets out a procedure for calibrating the dynamic test rig.

C2 PROCEDURE The floor, occupant restraint, stretcher, stretcher restraint system and manikin shall be replaced by a rigid mass of not less than three combined mass firmly attached to the test rig (sled).

C3 FRONTAL

C3.1 50th percentile manikin When the test rig (sled) is subject to a velocity change of not less than 49 km/h in the forward direction, a deceleration of between 24g and 34g shall be achieved within 30 milliseconds. The deceleration shall remain within the range of 24g to 34g for not less than 20 milliseconds, but deceleration values outside this range that occur for period of not greater than 1 millisecond may be disregarded.

C3.2 95th percentile manikin When the test rig (sled) is subject to a velocity change of not less than 49 km/h in the forward direction, a deceleration of between 15.2g and 24g shall be achieved within 30 milliseconds. The deceleration shall remain within the range of 15.2g to 24g for not less than 20 milliseconds, but deceleration values outside this range that occur for period of not greater than 1 millisecond may be disregarded.

C4 LATERAL (SIDEWAYS)

C4.1 50th percentile manikin When the test rig (sled) is subject to a velocity change of not less than 32 km/h in the lateral direction, a deceleration of between 12g and 22g shall be achieved within 30 milliseconds. The deceleration shall remain within the range of 10g to 17g for not less than 20 milliseconds, but deceleration values outside this range that occur for periods of not greater than 1 millisecond may be disregarded.

C4.2 95th percentile manikin When the test rig (sled) is subject to a velocity change of not less than 32 km/h in the lateral direction, a deceleration of between 9g and 19g shall be achieved within 30 milliseconds. The deceleration shall remain within the range of 10g to 17g for not less than 20 milliseconds, but deceleration values outside this range that occur for periods of not greater than 1 millisecond may be disregarded.

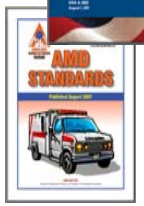
- "Restraint systems shall apply to all equipment and people carried in an ambulance…"
- Dynamic Testing - 50th & 95th percentile crash test manikins
- 24G in Forward and Rearward
- 10G in Transverse

For USA vehicles the testing standards and design requirements were not in keeping with accepted engineering technical vehicle and occupant safety standards with a number of highly misleading and potentially dangerous aspects to the standards and specifications and some practices that were well outside of anything that would be acceptable vehicle crashworthiness testing or design features (Fig 2a. and 2b) - such as the use of static loads to demonstrate crashworthiness performance and requirements which prevent the use of any crumple zones or impact absorbing structures (Table 1). hazards. The AMD/ KKK-F testing outlined was static testing only, with no acceleration (aside from gravity alone). Force = Mass x Acceleration, thus no inertial forces are described in the standard. There was no dynamic or impact crashworthiness testing required or mentioned to demonstrate safety performance of the rear occupant compartment of the ambulance at all.

RESULTS

In contrast to the extensive technical requirements for the Australasian Standard for the protection and restraint of the patients and the crew, the USA KKK-F has a one line section on protection of patients and crew (3.10.8.1) – *"Upholstered padding/cushions shall be provided at the upper interior areas of the door frames."*

Fig. 2a. USA KKK-F August 2007 and AMD Standards August 2007



- Static test only
- No dynamic test
- No definition /requirement for crash test manikin use
- No dynamic test of restraint for equipment

Fig. 2b. Implementation and application of AMD ambulance safety testing procedure completely outside of accepted automotive safety testing practice

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. For the AMD/KKK-F test protocols there is a complete failure to utilize any dynamic crashworthiness test protocols and the procedures described lack meaningful or established approaches to assess injury mitigation strategies as is used routinely in automotive safety (Fig 2b). Claims that successful AMD testing as specified in the AMD standard prior to August 2007 , reduced *"the possibility of injuries and fatalities ..... encountered in crashes or adverse forces that can result from a vehicle impact or roll over", and "minimize the possibility of failure by forces acting upon" occupants "as a result of vehicle crashes and/or sudden driving maneuvers"* –were not supported by any technical data, injury criteria or thresholds. 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. These statements which were in conflict with accepted, existing established technical science have now been removed from the August 2007 version of the AMD Standard. However now the current August 2007 AMD Standard makes no reference to procedures to provide any protection to the occupants of the ambulance under crash circumstances. Static test protocols do not consider any forces generated as a result of a crash impulse, e.g. inertia forces. As is uniformly known for 400 years Newton's 2nd law of motion states that the relationship between an object's mass (m), its acceleration (a), and the applied force (F) is F = ma.. The static protocols also do not take into consideration occupant kinematic movement and do not in any way reflect meaningful or accepted safety tests for occupant protection. Additionally the FMVSS exemption (Fig 3a.) is misleadingly addressed by the AMD position statement (Fig 3b.). The lack of FMVSS applicability beyond the front cab and the failures of the AMD protocols for the safety design of the rear compartment are highlighted in Fig 4.

By contrast the Australasian ambulance safety standards refer to dynami crashworthiness tests, use of standard crash test manikins and specific tes protocols, including detailed automotive dynamic test protocols and reflec existing automotive safety science.

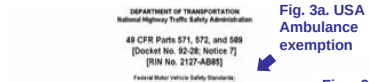


Fig. 3a. USA FMVSS 49 CFR Part 571 Ambulance rear compartment exemption

Fig. 3a. USA AMD Position Statement on Occupant Protection referring to FMVSS 49CFR Part 571

Fig. 4. Example demonstrating protective crumple zones for the front cab meeting FMVSS, and the absence of these protections in the rear compartment meeting AMD KKK

AMD Standard 001 August 2007: S5. c and S5.1 c

AMD standards ignorant of automotive safety principles – and specify that a 'successful structural integrity test' is one in which there 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."

LIMITATIONS

This analysis was a brief analytical technical report, and does not in any way address any specific vehicle or any specific vehicle or manufacturers design, but rather addresses the broad issue of the safety of the design standards.

CONCLUSION

There is marked disparity in the vehicle crashworthiness and passive safety design standards for ambulance vehicles in Australia and the USA - the USA design and safety performance standards being outside of accepted automotive safety engineering practice. There is a need for safety researchers, emergency medical service providers and ambulance vehicle designers to recognize and apply existing crashworthiness principles to reduce current ambulance design system failures, and for safety testing standards to address the areas that will enhance the safety performance and occupant protection of ambulance vehicles. This is key and fundamental information for a major fleet of essential service vehicles globally which in the USA has had minimal automotive safety attention or input to date.

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