Ambulance Safety Issues: Hazard Analysis and Crashworthiness, Where is the State of the Art?

Overview of the known hazards
Tools that can be applied to evaluating these safety issues
Current safety challenges
Some of the multidisciplinary techniques for optimizing the safety of the system as a whole.

Key Issues
- Mythology
  - The Emergency Medical Service personnel are safe
- Injury Hazards
  - Biokinetic
  - Chemical/Radiation
  - Physical/Mechanical/trauma – THE BIG PROBLEM
- Motor Vehicle Crashes are the highest cause of death at work – EMS has > 2X the mean national rate
- An R & D and Regulatory Gap
  - Occupational Health and Safety
    - the workplace is in a vehicle – exposure data are scant
  - Automotive Safety
    - a vehicle is the work place – ‘exempt’ from automotive research and regulation

Vehicle Safety
Vehicle Design
Safety Equipment Design
Vehicle and Safety Equipment Testing and Standard development
Safety policies

EMS Safety IS Complex AND Multidisciplinary
- Epidemiological Data Collection
- Ergonomic Research
- Automotive Safety
- Vehicle and Safety Equipment Testing and Standard development
- Risk Management
- EMS Safety
- EMS Policy
- PPE
- Driver Safety
- Regulations and Standards
- Fleet Safety Program

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Safety oversight of what and by .... whom
- Vehicle Safety
- Vehicle Design
- Safety Equipment Design
- Vehicle and Safety Equipment Testing and Standard development
- Safety policies

the EMS process
- communications/dispatch
- the patient
- restraining device/seat
- transporting device/transport
- paramedics/transport nurses, doctors & family
- patient monitoring equipment
- clinical care & interventions
- protective equipment
- the vehicle
- the driver/driving skill
- other road users
- the road

“Nation's Emergency Care System is fragmented, unable to respond to disasters”, says Institute of Medicine, June 14, 2006

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Director of Research
Objective Safety LLC, New York
Approach to hazard analysis and optimizing safety

- Unique nature of EMS, it bridges -
  - Public health
  - Public safety
  - Emergency medical care
  - Automotive and transportation safety
  - System safety engineering
  - Occupational health and safety
  - Risk management, liability
- It is paramount that the safety of this system be addressed with a comprehensive multidisciplinary approach.

C45 - A criminal offence to not act in a way that protects the worker

It is paramount that the safety of this system be addressed with a comprehensive multidisciplinary approach.

Balance of concerns and risk during transport

- Response and transport time
- Clinical care provision
- Occupant safety/protection
- Public Safety

 Benefit of Safety

- Any cost of addressing these issues is dwarfed in contrast to the huge burden of not doing so - in financial costs let alone the personal, societal, ethical and litigation costs

Is there an acceptable rate of morbidity and mortality for pre-hospital transport systems??

This is not acceptable

In the USA:
- ~ 5,000 crashes a year
- ~ One fatality each week
- ~23 pedestrians or occupants of other car
- Approximately 4 child fatalities per year
- ~10 serious injuries each day
- Cost estimates > $500 million annually
- USA crash fatality rate/capita 35x higher than in Australia

Firstly!

- An accident?
- or a predictable and preventable event

We should use the best safety practices demonstrated

Ambulance Safety Research: A New Field

- epidemiology
- engineering
- ergonomic

Development of an Effective Ambulance Patient Restraint

FEMA

Transport Canada, Ministry of Health

NIOSH, CDC

Weiss, et al MMWR

NIOSH, CDC
EMS Provider Fatalities
- 12.7 fatalities/100,000 EMS workers
- Greater than 2 X the national average
  (5.0 fatalities/100,000)
- Similar to Police (14.2/100,000) and Fire Fighters (16.5/100,000)

* Maguire, Hunting, Smith & Levick, Occupational Fatalities in Emergency Medical Services & Related Crits, Annals of Emergency Medicine, Dec 2002

and what is killing EMS?
- EMS personnel fatalities*
  - 74% transportation related
    - 1/5 of ground transport fatalities were struck by moving vehicles
    - 11% were cardiovascular
    - 9% were homicide
    - 4% needle sticks, electrocution, drowning and other

* Maguire, Hunting, Smith & Levick, Occupational Fatalities in Emergency Medical Services & Related Crits, Annals of Emergency Medicine, Dec 2002

A word about occupational transportation fatalities.

<table>
<thead>
<tr>
<th>Occupational transportation fatalities/100,000 workers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fire Fighters (16.5/100,000)</td>
</tr>
<tr>
<td>EMS workers</td>
</tr>
<tr>
<td>Police</td>
</tr>
<tr>
<td>5.0 fatalities/100,000</td>
</tr>
</tbody>
</table>

EMS Injuries*
- Higher than the injury rate for any private industry published by DOL
  - 34.6 injuries/100 fulltime workers per year
  - 1.5 x that of fire fighters
  - 5.8 x that of health services personnel
  - 7 x the national average


Predictable risks
- More often at intersections, & with another vehicle (p < 0.001)
- Most serious & fatal injuries occurred in rear (OR 2.7 vs front) & improperly restrained occupants (OR 2.3 vs restrained)
- 82% of fatally injured EMS rear occupants unrestrained**
- >74% of EMT occupational fatalities are MVC related***
- Serious head injury in >65% of fatal occupant injuries#
- >72% of fatal crashes EMS crashes during Emergency Use##
- More likely to crash at an intersection with traffic lights (37% vs 18% p=0.001) & more people & injuries/crash than similar sized vehicle##

Related literature:
- Ray AM, Kupas DF, Prehosp Emerg Care 2005 Dec; 9:412-415
- NIOSH, 2003
- Becker, Zaloshnja, Levick, Li, Miller, Acc Anal Prev 2003
- Kahn CA, Pirrallo RG, Kuhn EM, Prehosp Emerg Care 2001 Jul-Sep;5(3):261-9

Haddon/Baker/Runyan Phase-Factor Matrix

<table>
<thead>
<tr>
<th>PHASE</th>
<th>FACTOR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crash</td>
<td>Vehicle weight, road side infrastructure, vehicle design</td>
</tr>
<tr>
<td>Phase</td>
<td>座 belts, restraint, road design, median strips, solar reflectors</td>
</tr>
<tr>
<td>Event</td>
<td>Extrication, burn resistant fabrics, anti lock brakes, road side markings</td>
</tr>
<tr>
<td>Pre Event</td>
<td>Driving history, speeding,underlying causes</td>
</tr>
<tr>
<td>Pre Event</td>
<td>Patient, underlying health, drugs</td>
</tr>
<tr>
<td>Host</td>
<td>Age, gender, seat use, patient condition</td>
</tr>
<tr>
<td>Agent</td>
<td>Environment, complexity, weather, vehicle weight</td>
</tr>
<tr>
<td>Physical/Regulatory</td>
<td>Enforcement, laws, speed limits</td>
</tr>
</tbody>
</table>

EMS Research/Data Vacuum
- ? total no. of ambulances
- ? total no. of medics
- ? total no. of runs (per age & severity)
- ? total pt. miles (per age & severity)
- ? true crash fatality rate per mile
- ? crash injury rate
- ? adverse events

Goals
- Standards for safety
  - Policy based on science
  - Databases to demonstrate outcome

General Concerns
- Consequences can be predictable & likely preventable
- Costs of these adverse events are high in loss of life, financial burden and negative impact on delivery of EMS care
- Other high speed vehicles (eg. racing cars) have a different safety paradigm
- Design of interventions to mitigate injury is predicated on a valid testing model
- Complex both engineering and public health issues
Background: USA Problems

- No reporting system or database specifically for identifying ambulance crash related injury
- Rear passenger compartment, > 60cm behind driver - exempt from Federal Motor Vehicle Safety Standards (FMVSS)

USA Ambulances: FMVSS Exempt

- 1991-2000, 302,969 Emergency vehicles were involved in MVCs - 1,565 involving fatalities

In PA 1997-2001, ambulances were more likely than similar sized vehicles to be involved in:

- 4 way intersection crashes (43% vs 23%, p=0.001)
- Collisions at traffic signals (37% vs 18%, p=0.001)
- MVCs with more people injured (76% vs 61%, p<0.001)


Crash Prevention

- EVOC
- Tiered Dispatch
- The “Black Box”
- Intelligent vehicle design
- Appropriate policy

What do we know now??

- Intersection crashes are the most lethal
- There are documented hazards, some which can be avoided
- Occupant and equipment restraint with standard belts is effective. (Over the shoulder harnesses for patients should be used, with the gurney in the upright position where medically feasible)
- Some vehicle design features are beneficial - automotive grade padding in head strike areas, seats that can slide toward the patient
- Electronic Driver monitoring/feedback systems appear to be highly effective
- Head protection??

A number of potential interventions to enhance safety have been identified:

- Safety Policy
- Safety performance standards
- Vehicle crashworthiness
- Vehicle interior ergonomics
- Personal Protective Equipment design
- Driver training and simulation
- Safety and risk awareness modification
- Risk behavior modification
- Intelligent Transportation Systems (ITS)

The ‘workplace’ IS a vehicle

- Providers often in vulnerable positions during transport.
  - Bench seat
  - Captains chair
  - Standing or kneeling

View of Ambulance interior from rear
But what about head protection?

Preliminary Study: Attitudes to Head Protection in EMS

Would you consider wearing a helmet?

<table>
<thead>
<tr>
<th>Pre</th>
<th>Post</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>84%</td>
</tr>
<tr>
<td>No</td>
<td>16%</td>
</tr>
</tbody>
</table>

Automotive Safety World

The future of vehicle safety

Automotive Injury Triangle and Safety Development

Head

Vehicle

Purpose of ‘Black box’ Program

- Enhance Safety
- Improve Driver Performance
- Save Maintenance Dollars
- Aid Accident / Incident Investigation

Other monitoring devices

- Primarily to record events during and immediately preceding a crash
- Give no driver crash prevention feedback
- Administratively burdensome
- Intrusive
- Not demonstrated to be as effective in improving vehicle maintenance costs or as effective in modifying driver behavior long term

Full Vehicle Crash Tests - 2000

Test 1 - Right side impact

Test 2 - Frontal

Demonstrated Effectiveness

<table>
<thead>
<tr>
<th>Series</th>
<th>Test 1</th>
<th>Test 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Result 1</td>
<td>Result 2</td>
</tr>
<tr>
<td>II</td>
<td>Result 3</td>
<td>Result 4</td>
</tr>
<tr>
<td>III</td>
<td>Result 5</td>
<td>Result 6</td>
</tr>
</tbody>
</table>

Johns Hopkins University

Test 1 – Right side impact

1 – Target vehicle, Type I ambulance
2 – Bullet vehicle, Type II ambulance
Closing speed 44 mph

Test 2 – Frontal

1 – Bullet vehicle, Type III ambulance
2 – Target vehicle, Type II ambulance
Closing speed 34 mph
Global EMS Vehicle Safety Standards v Specifications and Guidelines

- EMS Safety and Performance Standards
  - Australia & New Zealand 4035
  - Common European Community (CEN) EN1789
- Non EMS Specific USA Standards
  - Aviation - FAA/CAA/JAA
  - Z15 – Fleet vehicles safety management
- USA EMS Specification & Guidelines
  - Purchase Specification: KKK & NTEA – AMD
  - Guideline: EMSC Dos and Don’ts
  - CAAS and CAMTS

American National Standard
ANSI/ASSE Z15.1-2006
Safe Practices for Fleet Motor Vehicle Operations

What Z15 encompasses

- Safety Program
- Safety Policy
- Responsibilities and Accountabilities
- Driver Recruitment, Selection and Assessment
- Organizational Safety Rules
- Orientation and Training
- Reporting Rates and Major Incidents to Executives
- Oversight

Z15 Incident Rates

- Incident rate based on number of vehicles operated:
  Incident rate = Number of incidents / Number of vehicles

- Injury incident rate based on number of vehicles operated:
  Injury incident rate = Number of incidents with injury / Number of vehicles

- Incident rate based on vehicle mileage:
  Incident rate = Number of incidents / Vehicle mileage

- Injury incident rate based on vehicle mileage:
  Injury incident rate = Number of incidents with injury / Vehicle mileage

- Incident rates based on service activity:
  Incidents per 10,000 transports = Number of incidents / Number of transports

- Vehicle injury rates based on work hours:
  Vehicle incidents per 200,000 hours = Number of injuries / 200,000 hours

Safety Management

- A Safety Culture
- Protective Policies
- Protective Devices
  - In the event of a crash
  - To prevent a crash
- Continuous Education and Evaluation

EMS Risk/Hazards

- Predictable risks
- Predictable fatal injuries
- Serious occupational hazard
- Public safety hazards
Safety Enhancements Being Implemented

- EVOC
- Tiered dispatch
- Monitoring & Feedback devices
- Helmets
- Optimized ambulance vehicle design
- New Standards

Future

- Meaningful Goals
- New policies
- New practices
- New standards
- New vehicles
- New technologies

Very Important Principle

Ambulance transport safety is part of a SYSTEM, the overall balance of risk involves the safety of all occupants and the public.

PREDICTABLE
PREVENTABLE
and
NO ACCIDENT

Conclusion

- Major advances in EMS safety research, infrastructure and practice over the past 5 years.
- There are clear and very serious safety risks and hazards in ambulance transport now documented.
- Technologies for safe vehicle design, occupant PPE and equipment restraint and driver performance are available.
- Development of substantive EMS safety standards is a necessity and a reality.
- Enhanced cross disciplinary collaboration in development of safety initiatives now exist.
- EMS is still way behind the state of the art in vehicle safety and occupant protection.

And…

- It is no longer acceptable for EMS to be functioning outside of automotive safety and PPE safety standards for protection of and protection of EMS providers and the public from injury and death.

Thank you! Any Questions?
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