THE INFLUENCE OF VEHICLE DESIGN ON INJURY RISK TO SERIOUSLY INJURED CASUALTIES AND RESCUE PERSONNEL.

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ID #: 05-0244

ABSTRACT

Seriously injured casualties in traffic collisions are frequently extricated from their vehicles by fire rescue services. This is achieved by employing space creation techniques to create apertures to provide access to casualties for the administration of medical assistance and to facilitate extrication of the casualty.

Data relating to a sample of 235 passenger car crashes was analyzed to identify the characteristics of such crashes. The data were selected on the basis of a geographical area for which a sample of the occupant extrication data from the Fire Service in that area was also available.

Analysis showed that there was a significant likelihood of rescue service involvement in crashes with an occupant with MAIS ≥ 3 injury severity.

Rescue service intervention was significantly more likely to occur when the occupants had received an injury of AIS ≥ 2 severity to the head, face or upper/lower limb body regions. Steering wheel intrusion, pedal disruption and front passenger compartment intrusion were also seen to significantly influence the need for rescue service intervention. In side impacts, only compartment side intrusion was found to be significantly present when rescue service intervention took place.

Fire service data are being analyzed to identify time intervals for extrication of casualties. It is perceived that these will increase due to the influence of modern vehicle design features such cable routing, pyrotechnic device location and non deployment of

Secondary Safety features. The study also discusses the influence of such features on the likelihood of increased injury risk to the casualty and rescue personnel.

1. INTRODUCTION.

Entrapment of occupants in motor vehicles following a Road Traffic Collision (RTC) is a frequent occurrence in a modern industrialized society. Rescue Services are called to the scene of such incidents that present a unique and challenging environment in which those individuals work.

Often there is an extremely short time frame during which the entrapped occupant has to be medically assessed, stabilised and freed from their damaged vehicle in order to be conveyed to hospital appropriately.

The potentially hazardous nature of the rescue operation adds a further complication to this scenario, as crews are required to conform to Health and Safety legislation and work as safely as possible.

It would appear that little has been published on the subject of inadvertent deployment of airbags during a rescue operation following a Road Traffic Collision. Some authors have identified the Post-Crash phenomena as the final part of an event comprising three major facets: accident causation, injury causation and post-crash circumstances.[1]

The post-crash phenomena has been described as, "an event which occurs after (a collision) and is not related to the cause of the collision or impact induced injuries, but which can result an increase of the injuries incurred or the possibility of additional injury"[1].

Other studies describe the process of gaining access to entrapped individuals in order for a medic to evaluate their medical status and then describe a second phase of the rescue employing extrication to release them.[2] Much research thus far has studied the incidence of fuel leakage, vehicle fires or water submersion as an additional factor in such scenarios.

Crawford[3] refers to the frequency of rescues at Road Traffic Collisions annually performed by the British

Fire Service; some 7500 in number. This compares to 4300 rescues from fires and 1000 rescues from other dangerous situations.

Purswell and Hoag[4] describe vehicles in the context of their escape worthiness and have performed tests analysing Vehicle, Passenger and Environmental characteristics and Vehicle/Passenger Condition in relation to the extrication process.

It would appear that few studies have been undertaken that investigate the length of entrapment time for occupants following a Road Traffic Collision or to establish the potential for inadvertently firing a Supplementary Restraint System Device as a consequence of the rescue operation.

Therefore a study was undertaken to investigate these issues and to attempt to quantify the extent to which rescue crews need to be aware of such occurrences to ensure safe working practices at the scene of a Road Traffic Collision.

2. METHODOLOGY

The data used in this analysis form part of a study into vehicle crash performance and occupant injury undertaken between the years 1998 and 2002 in Great Britain. The data form part of the Co-operative Crash Injury Study (CCIS) database which is maintained by the Transport Research Laboratory and is sponsored by a consortium of Motor Vehicle Manufacturers and the UK Department of Environment, Transport and Regions (DETR). The database only includes passenger cars, which were less than 7 years old at the time of the crash and were towed away to a garage or a vehicle dismantler. A more comprehensive overview of the CCIS study can be found in references [7&8].

The CCIS study requires a stratified sampling criterion to be applied for the crashes to be selected for further investigation. Some 80% of serious and fatal and some 10 – 15% slight injury crashes according to the UK Government's classification are investigated. The resulting sample is biased towards more serious injuries. Some 900 crashes were investigated annually.

Details of injuries are obtained from the Accident and Emergency departments in the region and H. M. Coroners' office. Each injury is rated on the six point Abbreviated Injury Scale (AIS)[9]

The CCIS database also contains some unique factors, such as delta – V.[10] Delta – V, for example, permits analysis of occupant injuries by crash severity.

The following criteria were used to select the data for the study:

- Vehicles: The struck vehicle had to be a passenger car aged less than 7 years old at the time of the crash.
- Severity: Only tow-away crashes are included.
- Occupant: All passenger casualties are included.
- Seat belts: Only drivers wearing a three point manual restraint system were included.
- Injury: The casualty sustained a serious or a fatal injury according to the Department for Transport classification.
- Crash location: Only collisions which occurred in the West Mercia region of UK are included.

These selection criteria resulted in a sample of 235 passenger car casualties.

Additional separate set of data was obtained form the Hereford & Worcester fire brigade. The data relates to collisions which occurred between the years 1998 to 2002 in the West Mercia region of the UK

The following 2 criteria were used to select the data for this study:

- Only collisions which occurred in the same geographical are included.
- Only collisions in which the casualty was trapped and needed extrication are included.

3. HAZARDS PRESENTED TO RESCUE CREWS

Quite often, casualties are trapped within the vehicle following a collision. Entrapment can occur due to one or more of several reasons; door jamming, obstruction of the door way, seat belt jamming, intrusion of the passenger compartment leading to entrapment of casualty body parts, injuries requiring stabilisation which would entail enlarging the access area into the vehicle and other factors.

As the design of passenger vehicles evolves and becomes more complex, new hazards are presented to crews attending the scene of Road Traffic Accidents. The use of new lubrication fluids to make production processes more efficient and the introduction of Liquid Petroleum Gas as an alternative fuel source are just two examples of how new potential hazards have presented themselves by either contamination or explosive risk.

Recent studies have shown that entrapment due to door jamming alone accounts for 25% in European cars[5]. Some 50% to 70% of the casualties suffer serious to fatal injuries. The injuries are mainly AIS $\geq$ 2 severities. The majority of these injuries are internal and skeletal, located to the head, face, neck, thorax, abdomen and spine body regions[6]
These casualties require immediate medical attention. This increases the urgency to gain access to the casualty and it is the Fire Service rescue teams who are responsible for providing access and extrication facilities to the casualty. It is imperative that this increased urgency does not put either the rescuers or occupants in further danger.

In doing so the rescue team has to be aware of the potential risks and guard their own safety while carrying out the operation and also ensure that there is no adding risk to the casualty at the same time.

The increasing presence of airbags in passenger cars adds to the risk of injury to both the rescues team and the casualty. The risk is mainly posed by undeployed airbags which may deploy as a during the rescue operation.

However, as a function of the rescue operation and particularly the space creation techniques, i.e. cutting into the vehicle structure utilised by the Fire Service, the accidental activation of Supplementary Restraint Systems (SRS) presents arguably the greatest risk.

Despite the frequency of occupant entrapment in modern vehicles fitted with multiple SRS devices, the amount of research into this developing phenomenon appears to be somewhat limited. At the time of publication, little appears to be known about the frequency of such events although undoubtedly there have been injuries caused to occupants and rescue personnel by inadvertent deployments.

It is for this reason that this study has been undertaken to investigate the issues relevant to the safe working of rescue crews at road traffic collisions and in the future to quantify the scale of the problem as it exists now and how potentially it could become more significant in the future with the increase of new vehicles on the road fitted with multiple SRS devices.

To that end, the Fire Service is developing new procedures to ensure the risk is minimized. Part of the problem appears to be the lack of information available to Rescue teams at the incident scene relevant to the varying discharge times of airbag capacitors (potentially in some cases up to 30 minutes post crash) which may provide the activation source for undeployed airbags and the positioning of pyrotechnic firing devices which may cause injury should they be transected by a cutting tool.

This paper will investigate the incidence of entrapment using selected data from the West Mercia Police region of the United Kingdom collected by the Co-operative Crash Injury Study (CCIS) and the nature of the Entrapment from analysed data supplied by Hereford and Worcester Fire and Rescue Service for the same geographical area.

4. FIRE AND RESCUE ATTENDANCE AT AN INCIDENT INVOLVING ROAD TRAFFIC COLLISION

In general terms, when a road traffic collision occurs and all three rescue services attend the role of each service is broken down into the following areas of responsibility:

The Police are responsible for closing off the scene and redirecting the traffic flow around it -or for more serious incidents will close a carriageway completely and divert traffic around the incident using alternative routes. The scene should also be "sealed" to ensure preservation of evidence.
The Ambulance Service has responsibility for the well being of the casualties at the scene and will lead any activity based on casualty care or handling. Ultimately, they will have the greatest influence of the three Services on how long a casualty can be trapped for with reference to the casualty status. They will make the decision as to whether the casualty requires rapid extrication (due to the nature of their injuries) or whether the casualty can be stabilised more effectively within the vehicle while the Fire Service utilise space creation techniques to facilitate the extrication process more effectively.

Therefore the Fire Service is responsible for the management of the Health and Safety issues that arise as a consequence of the nature of and difficulties presented by the scene and the joint Rescue operation. They will protect the Incident scene and will assist the Ambulance in the extrication of the entrapped casualties.

This paper utilises data from Hereford and Worcester Fire and Rescue Service, therefore it would seem apposite to outline the activities of that organisation in the extrication process at a typical Road Traffic Collision. It should be stressed that the following is an overview of a typical approach the Fire Service would adopt, but this may vary to encompass dynamic and unique nature of individual Road Traffic Collisions.

5. THE PROCESS OF EXTRICATION

Once a Fire and Rescue appliance has been mobilised to a Road Traffic Collision, the crew on board will have a clear understanding of the individual tasks required of them. There will be a basic plan of action agreed before arrival at the scene that will have the flexibility to adapt to the resources that may or may not be available when the crew attends.

For example if the Fire Appliance arrives before an Ambulance, at least one crew member will be detailed to administer basic First Aid to any casualty in need of it, a task that will be taken over by the Ambulance when they attend. If, as is often the case, the Ambulance arrives first then the Fire Crew member will be able to assist with another predetermined task.

5.1 Approach

As the Fire Appliance approaches the scene and visual contact is made, the appliance will slow down and proceed with caution. There are two main reasons for this: firstly, it is possible that there are “walking wounded” vehicle occupants who are in a dazed and unsteady condition who maybe behaving in an unpredictable manner, around the outer extremities of the scene. Secondly, a slow approach over the last hundred metres towards the scene will allow the Officer in Charge of the appliance time to make his initial assessment of the incident and to formulate a Plan of Action and a Dynamic Risk Assessment, to ensure the safety of the crew and other individuals within the scene itself.

5.2 Sectorising

It’s at this point, with the scene clearly in view that the Officer in Charge will divide the incident into Sectors to facilitate an efficient Command and Control structure. Typically in a two vehicle RTC one vehicle will be referred to as Sector One, the second as Sector Two. This allows oncoming crews to fit into the rescue operation with minimal disruption and focuses the efforts of individual teams to dedicated tasks.

5.3 Scene Safety

The Fire Appliance adopts a “fend off” position as it comes to rest in close proximity to the incident. This means that the driver will park diagonally across the carriageway, protecting the scene if the traffic lanes around it are still “live”. The equipment lockers containing the RTC Extrication equipment are found on the front nearside of the Appliance and thus as the crew get to work at the scene they are automatically shielded from other moving vehicles/hazards.

5.4 Vehicle Stabilisation

The first step in the Extrication process is to stabilise the scene and the vehicles involved. Initially, the crew will get a charged hose reel and a Carbon Dioxide Fire Extinguisher off the Pump as a precaution, so that if for some reason a damage vehicle catches fire, a prompt reaction will extinguish the flames and prevent the incident becoming more serious.

Given that a paramedic crew is already attending to an entrapped occupant, the Fire Crew will immediately stabilise the vehicle before any further Extrication work is done. This means preventing the vehicle from moving forwards or back and taking it off its suspension thus giving rescuers a stable platform to work on. This is achieved by “Blocking and Chocking” the vehicle with wedges and blocks on all four corners and wedging under each tyre to ensure stability, assuming that vehicle is still upright on all four wheels. In terms of Extrication the Fire Service consider there are three main scenarios – that where the vehicle is on its wheels, that were it is on its side and that when it is on its roof. Each scenario requires some form of Blocking and Chocking to achieve vehicle stability.

As this work is in progress the Officer in Charge of the Appliance will be liaising with the medics to decide upon which course of action to take in the extrication process. This will depend upon the severity and nature of the occupant’s injuries and which of the three scenarios, mentioned above, the vehicle is in. A decision at this stage may include spending more time at the scene to stabilise a casualty who is not in a life threatening condition or to perform a rapid extrication, if the casualty is in urgent need of more specialised care (i.e. surgery).

5.5 Glass Management
Whichever decision is taken the vehicles glazing is removed to make the cutting and space creation techniques utilised easier and safer, with the casualties being protected during this process by either plastic sheeting or a thin teardrop shaped shield.

5.6 Cutting and Space Creation Techniques
At this stage Fire crews are now ready to start the process of cutting and using space creation free entrapped occupants. This process is now beginning to present a significant problem potentially to Fire Crews if they are working on newer vehicles that are fitted with numerous passive SRS devices.

It has been noted that there have been incidences of SRS being inadvertently activated through rescue operations, despite a vehicle's power supply being isolated for a considerable amount of time prior to the accidental activation. (See appendix 1). It would appear that cutting through the wiring between the ECU and the device (that may typically run through an 'A', 'B' or 'C' pillar for a Side Impact Airbag or an Inflatable Tubular Structure) could potentially cause a short circuit in the system and result in an inadvertent activation.

Some Brigades in the United Kingdom are devising strategies to combat this problem. Often the protective plastic facia cladding within the vehicle interior is being removed to expose wiring for the supplementary restraints, gas generators for the cant rail inflatable structures or the pyrotechnic firing assemblies fitted in the 'B' Pillars of some vehicles to activate the pretensioning devices of the seatbelts. Inevitably, this will lengthen extrication times as the crews work to remove these facia.

In most cases if the vehicles on its wheels, as rescue teams go to work, the roof will be removed to allow the medics easier access to their charges. This will usually be facilitated by use of dedicated hydraulic cutting equipment (widely known as the "Jaws of Life). In some instances however, some Rescue Crews are now being instructed to remove the internal plastic facia from the internal surfaces of the 'A', 'B' and 'C' pillars to expose pyrotechnic firing devices, SRS gas generators and associated wiring, thus allowing the crews to avoid (wherever possible) cutting through these items. Inevitably, this necessary process will extend entrapment times for the occupants.

Once the roof has been removed, other techniques and tools can be employed to create space within the vehicle to release trapped occupants and allow medics to get spinal boards into the vehicle and adjacent to the casualties to ensure their safe removal from it. Spreading tools or hydraulic rams (the latter powerful enough to move vehicle bulkheads away from an entrapped occupant) are utilised in this process, as are pedal cutters and reciprocating saws if required. This part of the extrication is arguably the point at which the rescue crews and medics need to work absolutely in unison and adopt a "casualty centred" approach.

6. CASE STUDY: INADVERTENT FIRING OF SRS SYSTEM FOLLOWING RTC.

Following a recent road traffic collision incident attended by Appliances from both South Yorkshire and Nottinghamshire Fire and Rescue Services an inadvertent firing took place as a consequence of rescue operations.

An Alfa Romeo 147 (2003 registration) was involved in a front offside collision with a Mitsubishi Gallant. During the initial impact both the driver and passenger airbags on the Alfa Romeo activated and the vehicle had come to rest on its offside.

Whilst undertaking a roof fold down on this vehicle the rear `C` post airbags activated as hydraulic tools were in operation making a final (2nd) release cut in this post. This was some 30 minutes into the extrication - post impact, the ignition keys had been removed from the vehicle and both the `A` and `B` posts had already been cut.

ENTRAPMENT

The data from the CCIS database was interrogated to identify the entrapment status of the 235 casualties available in this analysis.

ENTRAPMENT

There were 129 casualties who were trapped and required extrication from the vehicle. This amounts to over half of the sample.

Table 1: Sample Size

	No Rescue	Rescue	Total
Number of Incidents	84	90	174
Number of Casualties	106	129	235

The injury distribution of the 235 casualties is shown in Table 2. It is observed that casualties who are trapped suffered more severe injuries.

Table 2: Injury Distribution of Casualties in Sample.

MAIS	Rescue Damage			
	No Rescue		Rescue	
	Number	Percentage	Number	Percentage
0	1	1	3	2
1	21	20	12	9
2	48	45	28	22
3	19	18	29	22
4	8	7	24	19
5	4	4	20	16
6	3	3	11	8
9	2	2	2	2
Total	106	100	119	100

7. EXTRICATION

It is seen from Table 3 that persons trapped are significantly more likely to require to be extricated from the vehicle. Some 86% of the casualties who were trapped required to be extricated from the vehicle compared to 45% of the casualties who were not trapped.

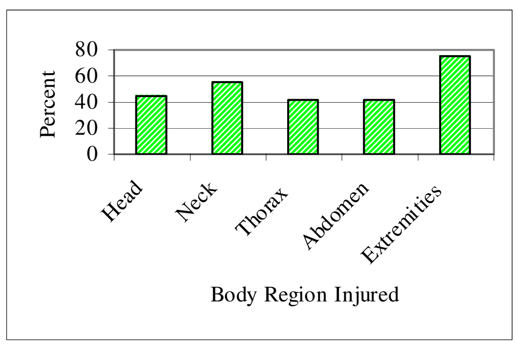
Most of the casualties requiring extrication are likely to have received severe injuries. In fact, nearly three quarters (72%) of the casualties received an injury of MAIS$\geq$3.The distribution of body regions suffering

Table 3: Extrication Status

Entrapment Status	Extrication Required			
	No		Yes	
	N	%	Nr	%
No	98	55.4	8	13.8
Yes	79	44.6	50	86.2
Total	177	100%	58	100%

injuries of AIS $\geq$ 2 severity are shown in Fig 1. It is seen that three quarters of the casualties received an injury to the extremities. However these injuries are not of a life threatening nature since they are of AIS $\leq$ 3 severities. The concern is for casualties with injuries to the head, thorax and abdomen body regions. Injuries to these body regions include life threatening injuries. Therefore safe and speedy access to these casualties is paramount. In attempting to affect extrication of these casualties, the rescue personal have to consider the presence of undeployed restraints. The inadvertent deployment of such restraints can be hazardous to both the rescue personnel and the casualty. Such risk is likely to increase with the development and installation of more restraints. This is likely to increase casualty entrapment and entrapment times as greater care will be needed to effect extrication.

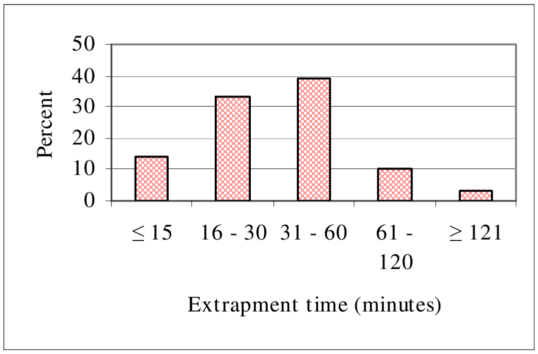
Fig 1: Body Regions Injured



7.1Entrapment Times

The distribution of entrapment times is shown in Fig2. It is observed that nearly 38% of the casualties are trapped in the vehicle for up to an hour. Some 33% of the casualties are trapped for 30 minutes and only about 14% of the casualties are trapped for less than 15 minutes. This would suggest that there is a potential risk posed by undeployed restraints to the majority of the casualties for up to an hour, since it is known that SRS systems can stay live for up to that time.

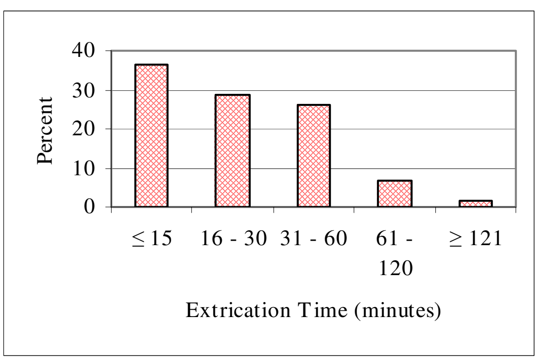
Fig 2: Entrapment Time



7.2 Extrication Times

Rescue personnel are also exposed to a similar risk whilst carrying out extrication procedures. The distribution of extrication times is shown in Fig 3. Some 37% of the extrications are completed within 15 minutes, whilst a further 28% are completed within 30 minutes. A quarter of the Extrications are completed within one hour. Therefore, a large majority of the rescue personnel are also exposed to this risk.

Fig 3: Extrication Times



CONCLUSIONS

Firm conclusions cannot be drawn from this limited study. However, the study shows that there is a potential risk of injury to the casualty and rescue teams with the increasing use of Supplementary Restraints.

A more in depth study currently being carried out will help to establish firm findings.

ACKNOWLEDGEMENT

This paper uses accident data from the United Kingdom Co-operative Crash Injury Study.

CCIS is managed by TRL Limited, on behalf of the Department for Transport (Vehicle Standards and Engineering Division) who fund the project with Autoliv, DaimlerChrysler, Ford Motor Company, LAB, Nissan Motor Company, Toyota Motor Europe and Visteon.

The data were collected by teams from the Birmingham Automotive Safety Centre of the University of Birmingham; the Vehicle Safety Research Centre at Loughborough University; and the Vehicle & Operator Services Agency of the Department for Transport.

Further information on CCIS can be found at http://www.ukccis.org

The Fire Service Data was supplied by Hereford and Worcester Fire and Rescue Service

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