HEAD AND FACE INJURIES TO CAR OCCUPANTS IN ACCIDENTS

- FIELD DATA 1983-1985

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ABSTRACT

A sample of 1603 car occupants was analysed to report on the frequency, severity and causation of head injuries in car accidents. The majority of the occupants were restrained in the front seats. The importance of head injuries and the type of blows causing head injuries in general was examined. It was found that 65% of fatalities had a head injury of AIS 3 to 6, and in the majority of cases brain injuries occur without skull fracture regardless of survival. It was also found that 64% of head injuries scored above AIS 2 were caused by objects outside the vehicle. Facial injuries were also examined and eye injuries were found to be rare. The steering wheel rim and hub were found to be the most common cause of non-surface facial injuries to drivers, whereas surface facial injuries were attributable to a variety of causes.

INTRODUCTION

There is broad agreement among car accident injury researchers worldwide that head injury is both the most damaging frequent injury and the most difficult to mitigate by vehicle design. Much work has been done in both experimental and field studies to examine head impact tolerance and the frequency and severity of injury in different accident circumstances. Arthurson (1) pointed to a predominance of the head among sites of critical and unsurvivable injuries, a finding repeated by Hobbs (2), and both these studies reported an associated head contact in all or nearly all cases. Hobbs in the same study noted the steering system as a frequent source of belted driver head injury to minor and moderate levels but seldom of serious injury. A similar picture was drawn of side header rail contacts in side impacts. Ashton (4) and Rutherford (5) emphasise the continuing high risk of serious head injury which for the driver appears not to be reduced by belt use in proportion with other body areas. Rutherford reports a general increase of serious brain injury to drivers coincident with the introduction of seat belt legislation. The long-term effects of brain injuries are an additional cause for concern. Rutherford (6) found symptoms of AIS 2 (11) brain injury remaining evident in 50% of patients at six weeks and in 15% at one year after the accident. Moreover the probability of at least such an injury to belted front seat occupants was calculated by Hobbs and Mills (7) to be 14% in frontal impacts of 20 m.p.h. delta-V, rising to 92% at 40 m.p.h. delta-V. Against this background, the paper examines the incidence, severity and causation of head injuries in car accidents in post seat belt legislation Britain.

STUDY STRUCTURE

The Accident Research Unit at the Institute for Consumer Ergonomics, Loughborough, is currently conducting research into the causes of injury to car occupants in road accidents. The research is funded by a sponsoring consortium comprising the Department of Transport, Ford Motor Company Ltd. and BL Technology.

The paper analyses data from 940 accidents involving 1603 occupants, occurring during 1983-5, in the counties of Leicestershire, Nottinghamshire, Derbyshire, Durham, Avon, Somerset and Wiltshire as described by Mackay (8). Accidents were randomly selected from police notifications of cars 5 years old or younger towed away from the scene. The sample was stratified by UK descriptions of severity (9) to increase the representation of serious- and fatal-injury accidents to 30%. Vehicles were examined using the procedures described by Otubushin (10), particularly for evidence of occupant contact with the vehicle interior or with any external objects associated with the accident. Injury information from hospital consultants, coroners, and occupant questionnaires was compiled and integrated with contact evidence to identify the sources of injuries.

The Abbreviated Injury Scale (11) was adopted to score injury severity. For the purpose of coding, injuries to the head are separated from injuries to the face and are then further divided into surface, skeletal and internal injuries. The group of head injuries is linked with its cause, as is the group of face injuries. In some sections of the paper the head and face have been separated and in other sections combined for analysis. The head is defined as the skull, the brain and its surface tissues including the ears. It excludes the surface tissues covering the forehead (frontal bone) which has been included as part of the face. The remaining structures above the neck are also defined as the face.

SAMPLE DESCRIPTION

Of the sample 89 (6%) car occupants died, 401 (25%) were seriously injured, 548 (34%) slightly injured and 565 (35%) uninjured. Table 1 shows the seat position and restraint use of all occupants. The majority, 58%, were drivers, 22% were front seat passengers and 19% were seated in the rear. It is not known where the remaining 1% were seated.

Table 1: Seating position and restraint use of all occupants.

RESTRAINT USE	SEAT POSITION			
	Front Right	Front Left	Rear	Not Known
Restrained	572	210	7	0
Unrestrained	60	20	291	0
Not known	304	114	13	12

The restraint use within the sample of 1603 occupants was 49%, 23% were known not to be wearing seat belts and the restraint usage of the remainder, 28%, was not known. In the U.K. there exists legislation to compel front seat car occupants to wear seat belts at all times, amongst these occupants 61% were restrained, 6% were unrestrained and the restraint use of 33% was not known. The seat belts of all the occupants were inspected and many showed no evidence of load markings so the restraint use was classified as not known. These occupants tended to be involved in lower speed impacts where load marks would not be expected. The size of the group with unknown restraint use is therefore significant. If this group of occupants is excluded the seat belt usage rate for the remainder of front seat occupants is 91%. The analysis within this paper has not been broken down by restraint use due to the size of the group of unknown restraint use and the close association of restraint use with seating position.

Table 2: Type of impact experienced by each occupant.

IMPACT TYPE	NO. OF OCCUPANTS	RELATIVE FREQUENCY %
Frontal	857	53
Side	304	19
Rear	72	5
Other	370	23
TOTAL	1603	100

The direction of the most severe impact for each occupant is shown in Table 2 which shows that 53% were involved in a frontal impact, 19% in a side impact but only 5% had rear impacts. 23% experienced either a rollover or multiple impact.

INJURY DISTRIBUTION - ALL OCCUPANTS

Table 3: Severity of injuries to all body regions.

BODY REGION	MAXIMUM AIS Occupant numbers and relative frequencies												TOTAL NO OF INJURIES
	1	%	2	%	3	%	4	%	5	%	6	%	
Head & face	379	(56)	199	(29)	33	(5)	25	(4)	24	(4)	15	(2)	675
Neck	210	(87)	4	(2)	16	(7)	0	(0)	2	(1)	8	(3)	240
Chest	337	(69)	65	(14)	34	(7)	18	(4)	17	(3)	15	(3)	486
Abdomen	91	(54)	7	(4)	20	(12)	22	(13)	28	(17)	0	(0)	166
Extremities	587	(70)	154	(19)	91	(11)	0	(0)	0	(0)	0	(0)	832

Table 3 shows the distribution of the maximum AIS for each injured body region of all 1603 occupants. The maximum score is the highest of any surface, skeletal or internal AIS for each body region. It should be noted that each occupant may have an injury to more than one body region.

The extremities were the most frequently injured body region followed by the head and face. The head and face were injured in 675 (42%) cases, and were the most frequent sites of injuries above AIS 3, accounting for 37% of all the AIS 4, 5 and 6 injuries.

Head injuries - related to death

Of the 1603 occupants in our sample 89 (6%) died, 58 (65%) of these having sustained a skull and/or brain injury, defined as a non-surface injury. The severity of all non-surface head injuries can be seen in Table 4.

Table 4: Non-surface head injuries by outcome.

OCCUPANTS	SEVERITY OF NON-SURFACE HEAD INJURY - AIS							TOTAL
	0	1	2	3	4	5	6	
Survived	1301	4	178	9	9	13	0	1514
Died	31	0	1	18	13	11	15	89
								1603

It is not possible to determine the number of occupants who died as a direct result of head injury since death can be made more likely by injuries to additional body areas, however, the role of head injury in fatality is shown in Table 5.

Table 5: Pattern of injuries of all fatally injured car occupants

LOCATION OF INJURIES OVER AIS 2	SEVERITY OF NON-SURFACE HEAD INJURY AIS							TOTAL
	0	1	2	3	4	5	6	
Head only	0	0	0	1	2	8	8	19
Head most severe of several injuries	0	0	0	0	4	1	6	11
Equally severe injuries to other body areas	0	0	0	0	0	0	1	1
More severe injuries to other body areas	31	0	1	17	7	2	0	58

There were 30 fatally injured occupants who had their most severe injury to the head, 19 of whom had no other life threatening injury. This accounted for 34% of all fatalities in the sample. One occupant had an equally severe head and chest injury and the remaining 26 occupants had their most severe injury to other body regions.

By comparing the numbers of those occupants that died from a head injury alone with those that survived with a head injury alone, the probability of death was estimated. Table 6 shows that the chance of dying with an AIS 5 head injury alone is 40% and that all those with an AIS 6 head injury died, as would be expected. One of the 9 occupants to sustain an AIS 3 head injury died with no other injury. The small numbers in each of the columns of Table 6 mean that there may be a significant error in the estimates of probability of death.

Table 6: Serious head injuries for occupants with no other serious injury.

OCCUPANTS	SEVERITY OF NON-SURFACE HEAD INJURY AIS				TOTAL
	3	4	5	6	
Survivors	8	4	12	0	24
Non-survivors	1	2	8	8	19
Probability of death	11%	33%	40%	100%	

HEAD AND FACE SURFACE INJURIES.

Surface injuries are those to the soft tissues covering the skull and facial bones and can be coded AIS 1 or AIS 2. There were 230 occupants sustaining surface injuries to the head and 448 with injuries to the face. 345 sustained surface head or face injuries only. Only 29 occupants sustained surface injuries to both areas with no corresponding non-surface injuries. The data are described in Table 7.

Table 7: Severity of injuries to the surface of the head and face.

BODY REGION	SEVERITY - AIS		TOTAL
	1	2	
Head	217	13	230
Face	401	47	448
TOTAL INJURIES	618	60	678

There were 618 AIS 1 injuries and 60 AIS 2 injuries. The AIS 2 injuries, particularly those to the face, can be judged to have the potential for long term disfigurement or scarring.

The contacts that caused surface injuries show similar distributions for head and face, they are therefore presented in a combined form. The most frequent contacts, accounting for two thirds of the surface injuries, are shown in Table 8.

Table 8: Cause of head and face surface injuries.

INJURY CAUSATION	TOTAL NUMBER	% KNOWN CONTACTS
Flying glass	38	14
Steering wheel	37	14
Windscreen	31	11
Side window glass	27	10
Seat	20	7
Roof	18	7
Facia	13	5
Other known contact	88	32
TOTAL	272	100

There were 122 unidentified contacts

No single injury cause type predominated. A total of 7 different contacts caused 68% of all surface injuries. The most common were flying glass (14%) and the steering wheel (14%), however, when counted together glazing materials were the cause of 36% of all head or face surface injuries.

NON-SURFACE FACE INJURIES

96 occupants sustained a skeletal face injury, most were single fractures but there were 19 occupants (20%) with more than one facial bone broken. Table 9 shows the nature and severity of all facial bone fractures.

Minor nose fractures were the most common but multiple face fractures were also frequent. There were 17 occupants with a fractured mandible alone and 8 others with a fractured mandible as well as additional facial fractures.

Internal injuries to the face were rare, being sustained by only 23 occupants. 17 of these were eye injuries and the remainder were to the mouth.

Table 9: No. of occupants with face skeletal injuries.

TYPE OF FRACTURE	AIS				TOTAL NUMBER	RELATIVE FREQUENCY %
	1	2	3	4		
Mandible	9	3	5	0	17	18
Maxilla	0	5	1	2	8	8
Zygoma	0	11	2	0	13	14
Nose	27	1	0	0	28	29
Orbit	0	1	1	0	2	2
Teeth	9	0	0	0	9	9
Multiple	4	10	3	2	19	20
TOTAL OCCUPANTS					96	100

There were 114 occupants that received either a skeletal or internal injury to the face but only 19 of these had injuries that were more severe than AIS 2. The contacts causing all non-surface face injuries are therefore shown together in Table 10.

Table 10: Cause of non-surface facial injuries.

INJURY CAUSATION	TOTAL NUMBER	RELATIVE FREQUENCY %
Steering wheel	43	31
Intruding external object	21	15
Windscreen	13	9
A-pillar	10	7
Seat	7	5
Other known Contact	55	33
TOTAL	149	100

There were 10 unidentified contacts

5 different contact types accounted for 67% of all non-surface face injuries, the most common was the steering wheel (31%) followed by intruding external objects (15%). All but 1 of the occupants having a non-surface face injury from the steering wheel were drivers and the steering wheel was responsible for 46% of the non-surface facial injuries to all drivers. Objects outside the vehicle caused injuries to 21 occupants.

Eye injuries.

There were 17 occupants with an injury to one or both eyes and 4 of these occupants received permanent visual impairment. These injuries are described in Table 11.

Table 11: Nature of eye injuries.

INJURY	TOTAL NUMBER	RELATIVE FREQUENCY %	NO. WITH SIGHT IMPAIRMENT
Surface lacerations or abrasions to eyeball	7	41%	0
Subconjunctival haemorrhage	7	41%	1
Crushed eye	2	12%	2
Optic nerve injury	1	6%	1
TOTAL OCCUPANTS	17	100	4

Sharp impacts resulting in surface lesions to the eye accounted for 41% of eye injuries. An equal number of subconjunctival haemorrhages occurred, caused by a blow either to the eye itself or adjacent to the eye. These are mainly short duration injuries not likely to impair sight. The contacts that caused these injuries together with any resulting sight impairment are described in Table 12.

Table 12: Cause of eye injury and sight impairment.

INJURY CAUSATION	NO. WITH INJURIES	NO. WITH SIGHT IMPAIRMENT
Flying glass	4	0
A or B pillar	4	1
Intruding object	2	0
Facia knobs & switches	2	1
Steering wheel	1	1
Cant rail	1	0
Not known	3	1
TOTAL	17	4

There were no eye injuries resulting from contact with a windscreen. Flying glass from previously broken windows caused 24% of the eye injuries. None of these injuries resulted in even partial long term sight loss, all were abrasions or lacerations to the eye surface. An equal number of eye injuries was caused by a relatively blunt impact with an A or B pillar.

NON-SURFACE HEAD INJURIES

Non-surface head injuries are injuries either to the skull or to the brain; 271 of the 1603 occupants (17%) had such an injury. These injuries are classified by AIS and skull or brain involvement in Table 13.

Table 13: Frequency and severity of all non-surface head injuries.

HEAD INJURY	SEVERITY OF NON-SURFACE HEAD INJURY - AIS						TOTAL
	1	2	3	4	5	6	
Skull fracture without brain injury	0	3	2	0	0	0	5
Skull fracture with brain injury	0	1	8	10	12	15	46
Brain injury without skull fracture	4	175	17	12	12	0	220
							271

176, 65% of all non-surface head injuries, received an AIS 2 brain injury. 175 had no skull fracture which by definition were brief periods of unconsciousness or loss of memory. Rutherford (6) has shown that these injuries, scoring only an AIS 2, can still produce symptoms for up to one year. Only 5 occupants of the 271 sustained a skull fracture without brain injury. Three of these sustained an AIS 2 injury to the vault of the skull and the other 2 had an AIS 3 basal fracture. All 5 were caused by a direct blow to the head.

46 occupants sustained both a skull fracture and associated brain injury. The frequency and severity of these injuries is shown by type of skull fracture in Table 14.

Table 14: Nature of skull fracture by maximum associated AIS score.

TYPE OF SKULL FRACTURE	SEVERITY OF NON-SURFACE INJURIES - AIS						TOTAL
	1	2	3	4	5	6	
Vault fracture alone with brain injury	0	1	4	2	7	0	14
Vault and base fracture with brain injury	0	0	2	2	4	11	19
Base fracture alone with brain injury	0	0	2	6	1	4	13
TOTAL OCCUPANTS	0	1	8	10	12	15	46

The vault alone and base alone were almost equally likely to be fractured, 14 occupants received vault fracture without base fracture and 13 received base fracture without vault fracture. A further 19 occupants sustained both vault and base fracture together. All 15 unsurvivable AIS 6 head injuries occurred when the base was fractured.

The most common type of non-surface head injury was brain injury without skull fracture as described in Table 13. There were 220 such occupants 179 (81%) of whom had brain injury below AIS 3, corresponding to unconciousness for less than 15 minutes. The remaining 41 constituted 47% of all the brain injuries of AIS 3 or above. The nature of the force causing these brain injuries is shown in Table 15 together with their severity.

Table 15: Severity and frequency of brain injury without skull fracture.

INJURY CAUSATION	BRAIN AIS						NO. OF OCCUPANTS
	1	2	3	4	5	6	
Direct blow	4	98	11	7	9	0	129
Non-contact injury	0	32	2	2	1	0	37
Not known	0	45	3	2	2	0	52
Other	0	0	1	1	0	0	2
							220

The group of injuries classed as "other" were either a consequence of a neck injury or hysterical unconciousness.

Of brain injuries above AIS 2 where the injury cause was known, 27 (84%) were from a direct blow. 13 of these were caused by a head contact and 14 by a face contact of which 10 also resulted in facial bone fracture.

38 occupants sustained a brain injury without a skull fracture or an identified head or face contact. These 38 occupants had no surface injury to the head or face and there was no evidence of a contact either within or outside the vehicle. Most commonly the severity was AIS 2, there were 32 occupants with this injury and they represented 18% of all AIS 2 brain injuries. Of these 32 occupants, 87% were seated in the front seats and 91% of this group were restrained. The remainder were rear seat occupants and all of these were unrestrained. There were a further 5 cases with a more severe non-contact brain injury and these 5 occupants represented 6% of all the casualties with brain injury of AIS 3 or above. Appendix 1 gives a case by case description of these occupants. Four occupants with these severe head injuries died, but each also had potentially fatal neck or chest injuries. No occupant died solely of a non-contact head injury.

Contacts causing non-surface head injury.
Analysis of the contacts that caused skull fracture or brain injury showed a significant difference between minor and more severe injuries. They are, therefore, presented separately. 98% of the minor non-surface head injuries are AIS 2 unconciousness not skull fracture, whereas 53% of the more severe injuries involved skull fracture. The contacts that caused the minor injuries are shown in Table 16.

Table 16: Cause of AIS 1-2 non-surface head injuries.

INJURY CAUSATION	TOTAL NUMBER	% KNOWN CONTACTS
Non-contact injury	32	22
Steering wheel	32	22
Side header rail	10	7
A-pillar	9	6
Windscreen	8	5
Side window glass	8	5
Other known contact	49	33
TOTAL	148	100

There were 48 unidentified contacts

6 contact types accounted for 67% of all injuries. The most frequent of these causes were steering wheel contact and non-contact injury, i.e. an injury caused by deceleration of the head from forces transmitted through the

neck. These two contacts accounted for 44% of all minor non-surface head injuries. Glazing materials again caused frequent injury being responsible for 10% of the minor non-surface head injuries (AIS 1 or AIS 2).

The contacts that cause the more severe head injuries are quite different. Only 3 types accounted for 74% of all major head injuries, these are described in Table 17. Of the 72 identified contacts 38 (53%) were with the object having the major impact to the occupant's vehicle. 29 of these external objects were vehicles, mainly heavy goods vehicles, and 9 were roadside objects, such as trees or lamp posts. All 38 external objects intruded into the occupants survival space. The restraint use of those sustaining contacts with an intruding object was 76% and 87% were front seat occupants. In addition there were 8 further occupants who were completely or partially ejected from the vehicle. They sustained major head injury by striking the ground or another external object. Only one of the ejected occupants was wearing a belt and this was a driver, the other 7 were rear seat occupants. Objects outside the vehicle accounted for 64% of major head injuries.

Table 17: Cause of AIS 3-6 non-surface head injuries.

INJURY CAUSATION	TOTAL NUMBER	% KNOWN CONTACTS
Intruding external object	38	53
External object (ejection)	8	11
A, B, D pillars	7	10
Other known contacts	19	26
TOTAL	72	100

There were 14 unidentified contacts

Head or face injuries from steering wheels

92 occupants had an injury to the head or face as a consequence of striking a steering wheel. Of these 91 were drivers and the other a front seat passenger. These casualties sustained 120 separate head or face injuries from 131 contacts, 96% of these were wearing a seat belt and 95% were in a frontal impact. The injuries and contacts of the drivers are examined in more detail.

36 drivers received a head injury associated with a steering wheel contact. The nature of these injuries is shown in Table 18. The most common injury was AIS 2 unconciousness or amnesia, the next most common injury was a soft tissue injury. Two drivers sustained a serious brain injury from the steering wheel.

Table 18: Drivers' head injuries from steering wheels.

MOST SEVERE INJURY		NO. OF DRIVERS
AIS 1	Cuts, bruises or abrasions	4
	Drowsiness	2
AIS 2	Amnesia	8
	Unconciousness less than 15 mins	20
AIS 3-6	Severe brain injury	2
TOTAL DRIVERS		36

29 drivers had a brain injury with no head contact, but all had a face contact on the wheel and 15 had a facial bone fracture. There were 84 drivers with a face injury as a consequence of a steering wheel contact. The nature of these injuries is shown in Table 19.

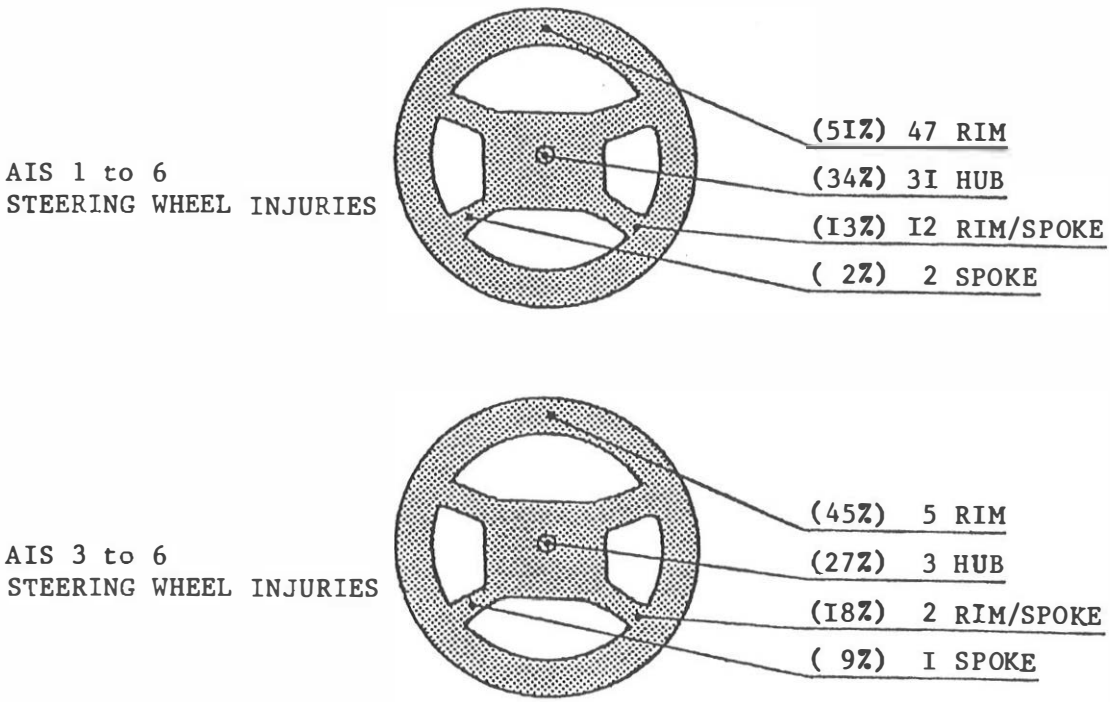
Table 19: Drivers' face injuries from steering wheels.

MOST SEVERE INJURY	NO. OF DRIVERS	TOTAL
AIS 1 Cuts, bruises and abrasions	41	
AIS 2 Cuts, bruises and abrasions	5	46
Nose fracture	17	
Tooth fracture	2	
Zygoma fracture	3	
Maxilla fracture	1	
Mandible fracture	8	
Multiple fracture	5	36
Optic nerve injury	1	
Mouth laceration	1	2
TOTAL DRIVERS		84

46 of these casualties had a surface injury alone, 5 of which were of AIS 2. There were 31 with a single facial bone fractured and 5 with multiple facial bone fractures. Nose fractures were the most frequent type of fracture followed by mandible fractures. The zygoma was only rarely broken.

The location on the steering wheel of the contacts causing head or face injuries was determined. They are shown for all injuries and for injuries above AIS 2 in Figure 1.

Figure 1: Location of drivers' steering wheel contacts.



Injuries of all severities most commonly came from the steering wheel rim and then from the hub.

To examine the relationship of the severity of the face injury with impact severity the CRASH 3 computer program was used to determine the vehicle Delta-V of each occupant in the sample where possible. The Delta-V for those with any steering wheel injury to the face could be calculated in 50% of cases and the average of these was 48 kph. The corresponding measures for injuries above AIS 1 and injuries above AIS 2 were 48 kph and 42 kph respectively. It is not fully understood why the most severe facial injuries do not arise in the most severe impacts.

The 50th percentile Delta-Vs were 38 kph for surface injuries alone, 41 kph for non-surface head injuries and 48 kph for non-surface face injuries. 75% of occupants with facial bone fracture were involved in collisions below 56 kph, and 75% of brain injuries from steering wheels occurred below 64 kph.

The effect of contact with an intruding steering wheel was examined. It was found that an intruding wheel was no more likely to cause head injuries over AIS 1 than a non-intruding wheel. The severity of face injuries tended to be higher when the wheel was intruding, 31% of injuries from an intruding wheel were above AIS 2 compared to 19% from a non-intruding wheel. This is not a statistically significant difference.

DISCUSSION

Injuries to the face and head have been shown to be particularly important among those car occupants fatally or seriously injured. The head or face is the site of most injuries of AIS 4 and above, and 65% of those who died had a head injury of AIS 3 or above. These findings agree with those of previous studies (1, 2). Any reduction in the incidence of these injuries would significantly affect the numbers of car occupants seriously or fatally injured.

The study has shown that 61% of serious head injuries arise from contacts with objects outside the vehicle. Most of these were with objects, typically goods vehicles or trees, that intruded into the survival space of the car occupants. While some benefit might be found from addressing the problem of car to heavy vehicle compatibility there are no clear aspects of vehicle design that would seem to have the potential for large reductions in the numbers or severities of these injuries. There are, therefore, some types of accident that have to be considered as unsurvivable. A lesser proportion of these occupants suffering severe head injury was ejected from the vehicle and their injuries might well be moderated by preventing this.

The steering wheel has been shown to be a major cause of facial bone fractures, particularly nose and mandible fractures, and AIS 2 brain injury to drivers as found by Hobbs (2). Surface head and face injuries are also frequent following a steering wheel contact. A head form impact test, based on a procedure developed by Petty (13) has been proposed as a European standard for steering wheel performance. This study has shown that any test procedure needs to reflect the injury mechanisms and injury tolerance levels of the facial bone fractures and the AIS 2 brain injuries that result from steering wheel contact. It does not appear correct to use a tolerance level that corresponds to an AIS 3 brain injury. A test should discriminate between the frequent injuries found to arise from rim and hub contact and the less frequent spoke contacts. Finally 75% of serious injuries from any part of the steering wheel were found to occur below 56 kph in the case of facial fractures and 64 kph in the case of brain injury so the severity of test conditions should reflect this.

This study has not examined the mechanism of non-contact head injury in detail and it has not been established whether the head movement in these cases is principally rotational or longitudinal. Aldman (12) has highlighted the need for further investigation of rotational head injury, and the incidence of non-contact injuries within the current study supports this need.

CONCLUSION

- Injuries to the head are the most frequent of all injuries above AIS 3 and are sustained by 65% of all car occupants who die.
- Most non-surface injuries to the skull or brain arise from a direct blow; most brain injuries occur without skull fracture regardless of severity.
- Head injuries above AIS 2 are caused by objects outside the vehicle in 61% of cases.
- Amongst all occupants, non-surface head injuries of AIS 2 and below most frequently occur with a steering wheel contact or with no head or face contact at all.
- The most common cause of non-surface face injuries from the steering wheel is from the rim or hub.
- Eye injuries are infrequent and are mostly caused by blunt trauma. Glazing materials cause 24% of all eye injuries, but cause no long term sight impairment.

FUTURE WORK

Our future work will examine non-contact brain injury in more detail, the effect of steering wheel construction on head and face injury, and the nature of impacts and contacts causing death to car occupants.

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APPENDIX 1

AIS 2 NON-CONTACT HEAD INJURIES

AIS 3 NON-CONTACT HEAD INJURIES

CASE NO. 1

Female aged 44 years. Unrestrained right rear seat passenger. Fatally injured and confirmed dead on arrival at hospital.

Injuries. Post Mortem report revealed small punctate cuts to right forehead; subarachnoid haemorrhage around base of skull. (NB. There were no face or head skeletal injuries.) Injuries to other body areas included fractures to right clavicle and right ribs with haemothorax; transected aorta; haemomediastinum; surface injuries to the extremities.

Impact type. 2 o'clock oblique right side impact into another car. Direct contact over complete passenger compartment. Maximum 10 cm. crush into rear seating area. Delta-V calculated at 36 km/hr using the CRASH 3 program.

Kinematics. Struck side occupant. Right shoulder and chest contacted rear door side panel supported by intruding other vehicle. Head would have continued through window aperture with no object in line to strike and caused non focal deceleration injury to the brain. The surface injuries to the forehead were attributed to flying glass.

CASE NO. 2

Male aged 39 years. Restrained driver. Fatally injured and confirmed dead on arrival at hospital.

Injuries. Post mortem report revealed superficial injuries to the face; diffuse subarachnoid haemorrhage over superior surface of the brain. (NB. There were no face or head skeletal injuries.) Injuries to other body areas included almost total severance of the trachea; fractures to the right 2nd and 3rd ribs and left 4th rib in the mid-clavicular line; gross contusion to the spleen; fractures to the extremities.

Impact type. Very high energy. 1 o'clock frontal impact into a HGV. Gross underrun therefore Delta-V not calculated.

Kinematics. Trachea contacted intruding steering wheel rim with chest onto hub and spokes. Head would have continued to decelerate through windscreen aperture, finally nodding onto already broken laminated windscreen. There was sufficient clearance for the head to decelerate without making contact. The surface facial injuries were attributed to the broken windscreen.

AIS 4 NON-CONTACT HEAD INJURIES

CASE NO. 3

Male aged 19 years. Restrained front seat passenger. Fatally injured and confirmed dead on arrival at hospital.

Injuries. Post Mortem report revealed 3 cm. superficial laceration involving left earlobe; petechial haemorrhages scattered throughout the white matter of the brain. (NB. There were no face or head skeletal injuries.) Injuries to other body areas included posterior fractures to 4th and 5th left ribs; interstitial haemorrhage within lungs; large left haemothorax; transected aorta; fractured left femoral shaft.

Impact type. 9 o'clock impact into a telegraph pole onto centre of left passenger door with 60 cm. intrusion. Delta-V calculated at 56 km/hr using the CRASH 3 program.

Kinematics. Struck side occupant. Left side of chest contacted intruding door which was supported by the pole. Head did not hit the pole. Non-focal deceleration injury to the brain. The surface face injury was attributed to the side window glass.

CASE NO 4

Female aged 39 years. Restrained front seat passenger. Seriously injured and detained in hospital for 69 days due to leg traction. Made full recovery from head injury.

Injuries. Hospital case notes and occupant's questionnaire reported a subdural haemorrhage right side occurring 2 days post accident. (NB. There were no face or head surface or skeletal injuries.) Injuries to other body areas were fracture to left 3rd rib; fractured pelvis; compound fractures to both lower extremities.

Impact type. 10 o'clock oblique side impact with another car involving the front left seating area and engine compartment. Delta-V calculated at 38 km/hr using the CRASH 3 program.

Kinematics. Struck side occupant. Side structure intruded into the passenger compartment causing chest and hip injuries. There were no contacts for the head found and the occupant stated "no external head or face injuries". Hospital consultant suggests injury caused by "sudden jerk of the head".

AIS 5 NON-CONTACT HEAD INJURY

CASE NO. 5

Female aged 21 years. Restrained driver. Fatally injured and confirmed dead on arrival at hospital.

Injuries. Post Mortem report revealed right sided facial abrasions and lacerations; complete dislocation of skull on atlas; pons contusion; subarachnoid haemorrhage. (NB. There were no face or skull skeletal injuries.) The dislocation completely exposed the top of the cervical spine with "the neck appearing to have been stretched". (AIS 6 was assigned to the neck body area and AIS 5 to the head for the pons contusion.) Injuries to other body areas included abrasions to the right side of the neck; fractures to the 5th and 6th right ribs and 2-5 left ribs in the mid-clavicular line; congestion of the lungs with "blast like" injuries to the tissues indicative of sudden airway obstruction; complete transection of the aorta; lacerated myocardium with heart chamber rupture; severe abdominal injuries; surface and skeletal injuries to the extremities.

Impact type. 1 o'clock highly offset frontal into another car. Involving front and right wing. 63 cm. intrusion at facia level. Delta-V calculated at 80 km/hr using the CRASH 3 program.

Kinematics. Massive intrusion at footwell and facia level, A pillar and door moved inboard and backwards. Footwell intrusion would have forced occupant upwards, she contacted her chest on the steering wheel rim (clothing fibres and marks found). Her head continued forwards through side window aperture and the neck contacted the top of the door near to the deformed intruding A pillar. NB. The "blast like" injuries are consistent with sudden trachea compression and chest loading. It was felt that the facial injuries could have been sustained as the head went forwards with her face brushing past the jagged metal in this area, or as her head came to its final resting position.