INTRACRANIAL OR NECK INJURY IN BELTED CAR OCCUPANTS

by

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1. INTRODUCTION

A large amount of experimental work has been undertaken in different parts of the world using cadaver, human volunteer or animal material in attempts to determine tolerance limits of the human brain to deceleration. A rather lesser amount of similar experimental work has been carried out on injury tolerance limits for the neck.

A more direct approach is to investigate the severity and incidence of injury to these regions of the body in vehicle occupants involved in road accidents, and to relate the injury patterns found to direction and to severity of vehicle impact; and later, by reproducing under controlled laboratory conditions the circumstances of the accidents, using anthropomorphic dummies or test devices, to establish tolerance levels to injury in terms of loads measured in these tests.

During the past 10 years over 2000 vehicle occupant casualties have been seen by the Traffic Medicine Section of the Transport and Road Research Laboratory (TRRL). For the purpose of this paper we have confined our analysis to this accident injury material and have used those 117 front seat car occupant casualties contained within the sample who were wearing lap and diagonal seat belts, who were involved in frontal impact accidents and had either been detained in hospital because of injury received to one or more parts of the body or had been killed. Each casualty was medically examined by one of the authors of this paper (E.G. or N.C.). Subsequently their vehicles were investigated and the damage and circumstances of the accidents recorded.

The analysis presented here does not purport to assess the effectiveness of seat belts, which have been shown elsewhere to effect substantial reductions in severity of injuries.

2. EXPERIMENTAL FINDINGS

Although a great deal of experimental work has been performed in various countries no universally accepted figures have yet been established for head and neck injury tolerance. The United

States F.M.V.S.S.208 sets a head injury criterion (H.I.C.)* limit of 1000 based on work by Patrick and others but there is evidence to suggest that this is not applicable to all accident situations. Ommaya and Thibault (1973) have suggested that rotational acceleration of the head is of importance in the production of diffuse brain lesions and a limit of 1800 rad per sec^2 has been proposed for concussion (Ommaya et al 1970).

Experimental work on the tolerance of the neck to angular acceleration is less well documented. Recent work includes a paper by Clemens and Burow (1972) using human torsos in simulated head on and rear end vehicle crashes in which cervical spine injuries were recorded as occurring in both impact directions, and Gadd et al (1971) have proposed neck tolerance limits of 60^{o} for lateral angular deflection relative to the torso and of 80^{o} in hyperextension.

3. TRRL ACCIDENT-INJURY SAMPLE

Although there were a few cases with evidence of minimal direct loading of the neck by the belt i.e. minor abrasions, the head and neck in belted occupants is not normally subjected to direct loading by the belt but there may be head contact with some interior structure of the vehicle. Because of the anatomical complexity and the clinical importance of this part of the body it is therefore of particular interest to look at the extent and severity of head injury or neck injury with or without head contact amongst seriously or fatally injured belted occupants, and at the same time to associate the severity of injury received with the vehicle collision severity in frontal impact accidents. Using this technique some indication of injury tolerance for the head and neck may be obtained in terms of accident severity for belted occupants in the frontal impact collisons studied.

An indication of collision severity for the occupants is given by the change in velocity of the vehicle estimated to have taken place during the impact. The velocity changes of the vehicles occupied by the casualties in the sample were therefore estimated from the damage to the vehicles and the circumstances of the impact. There was not always sufficient data available for these estimations to be made but for the 55 vehicles which

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* Head Injury Criterion (H.I.C.) is a mathematical computation based on the resultant acceleration (a) of the centre of gravity of the head during impact with a part of the vehicle; t_1 and t_2 are any two points in time.

$$H.I.C. = \left[\frac{1}{t_2 - t_1} \int_{t_1}^{t_2} a \, dt \right]^{2.5} (t_2 - t_1)$$

have been calculated the mean vehicle velocity change was 49km/h. Above this level of velocity change it is known from previous studies (Harteman and Tarriere 1974) that fatal and serious injuries predominate, so the sample examined here contains a fair representation of severe collisions.

In assessing severity of injury we have used an injury classification based upon clinical criteria (TRRL Leaflet LF 130 1974). In describing the direction of impact on the vehicle a frontal impact has been defined as one in which the main impact force was applied at 45° or less from, and on either side of, the longitudinal axis of the vehicle.

3.1 Injuries to the head or neck without evidence of head contact

The numbers of belted occupants without evidence of head contact are shown in Table 1.

TABLE 1

Number of casualties with intracranial or neck injury amongst 21 seriously injured and 3 fatally injured belted occupants with no head contact

Region Injured / Severity of injury	Head	Neck
No injury	18	16
Minor injury	2	6
Moderate injury	3	1
Severe injury	1	1
Fatal injury	-	-
All injury severities	24	24

There were 21 seriously injured and 3 fatally injured belted occupants who sustained no head contact. We have defined no head contact as a casualty in which there was no clinical or pathological evidence of surface injury to the head and no evidence of the head hitting a part of the car or any other object. It will be seen from the table that most of these occupants received no intracranial or neck injury. Only one received a severe intracranial injury, a bilateral sixth nerve palsy which resulted in

permanent disability, and one received a severe neck injury, a subluxation of the cervical spine (C4-C5) which also resulted in some permanent disability. The other brain injuries shown in the table consisted of minor or moderate concussion none of which resulted in permanent disability; and the minor or moderate neck injuries shown were stiff necks with no radiological evidence of injury, none of which resulted in permanent disability.

Although the number of belted casualties without head contact is small the data indicate that, where there was no evidence of head contact, clinically important injury to the cranial contents or to the deep structures of the neck was infrequent in the frontal impact accidents studied. Nine of the casualties were drivers and 15 were front seat passengers. The mean of the velocity changes for the involved vehicles for which calculations have been made was 48km/h; the maximum velocity change was 58km/h. It would seem therefore that for belted occupants involved in frontal impact collisions sufficiently severe to cause serious or fatal injury the limit of tolerance of the head or neck to deceleration injury without head contact is not often reached even in relatively severe collisions.

3.2 Injuries to the head or neck with head contact

It is worth considering briefly the occupants in the sample with head contact. There were 93 casualties in which the head hit or was hit by some interior structure, 8 of whom were fatally injured, 2 as a result of head injury and one as a result of neck injury caused by head impact. Amongst the 93 seriously or fatally injured casualties there were 19 who sustained severe head injury, but no cases with severe neck injury were seen although there was one case of fatal neck injury. Table 2 gives a breakdown of severity of injuries to the head or to the neck amongst the seriously or fatally injured casualties with head contact.

TABLE 2

Number of casualties with head or neck injury amongst 85 seriously injured and 8 fatally injured belted occupants with head contact

Severity of injury \ Region of Body	Head	Neck
No injury	2	80
Minor injury	22	11
Moderate injury	48	1
Severe injury	19	-
Fatal injury	2	1
All severities	93	93

The leading cause of severe injury to the head was the steering wheel, in drivers. This feature of injury causation in belted drivers, which has been pointed out on previous occasions (Grime 1968, Mackay et al 1973, Grattan and Hobbs 1974), emphasises the need for further consideration of design of the steering wheel assembly to alleviate injuries to this area of the body. It will be noticed (see Tables 1 and 2) that the proportion of neck injuries more severe than minor (2 out of 93) was less amongst those seriously or fatally injured occupants with evidence of head contact than amongst those without head contact (2 out of 24). On the other hand the proportion of injuries more severe than minor to the head was greater amongst those seriously or fatally injured casualties with head contact (69 out of 93) than amongst those without evidence of head contact (4 out of 24). It may be that the neck is protected from excessive movement by head contact but at the expense of a greater severity of head injury. 76 of the casualties were drivers and 17 were front seat passengers. For the cases with evidence of head contact the mean velocity change of the vehicles for which calculations were made was 49 km/h; the maximum velocity change was 68 km/h.

4. CONCLUSIONS

Two main conclusions can be drawn from the results of this in depth study of 117 seriously or fatally injured belted front seat occupants of cars, all of whom were involved in frontal impact accidents.

1. Amongst the seriously or fatally injured belted occupants without evidence of head contact clinically important injury to the cranial contents or to the deep structures of the neck was uncommon.

2. Amongst the seriously or fatally injured belted occupants with evidence of head contact the proportion of casualties with neck injury more severe than minor was less than amongst those without head contact although the number with head injuries was greater.

For these two groups of casualties there was no significant difference in the mean of the velocity change for the involved vehicles for which calculations were made: 48 km/h for casualties without head contact and 49 km/h for those with head contact.

5. REFERENCES

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