THE RELEVANCE OF THE BIOMECHANICS OF IMPACT TO THE ASSESSMENT OF HEAD INJURED PATIENTS IN THE ACCIDENT & EMERGENCY DEPARTMENT

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ABSTRACT

Assessment of the head injured patient in the Accident and Emergency (A & E) Department still poses a significant problem. Guidelines for skull radiography after apparently minor head injuries rely heavily on the degree of scalp bruising and swelling present on examination. This in turn may be influenced by delay in presentation of the patient. Clearly a neurological examination is essential but some biomechanical factors may also have potential prognostic value in identifying the small number of patients who are at risk from developing complications.

This paper presents the results of a study of every head injured patient attending the Salford A & E service over a twelve month period. In addition to the more usual data concerning clinical status on arrival and outcome, consideration was given to the speed of impact and the object with which the head collided. The latter was then correlated with the severity of injury sustained. Severity has been classified by the state of consciousness on arrival, the period of post traumatic amnesia (PTA) and the presence of a skull fracture. The site of impact was also recorded and correlated with the duration of PTA.

"Sharp" head injuries were more frequently associated with local damage to the scalp whereas "blunt" injury produced longer PTA. Post traumatic amnesia was more commonly prolonged in those patients whose head injury was sustained without direct damage to the scalp. There was a positive association between speed of impact, duration of PTA and presence of skull fracture.

These results support Gennarelli's hypothesis for cerebral concussion. The above mentioned biomechanical parameters have been used in the A & E department to redefine and safely restrict the indications for skull radiography.

INTRODUCTION

There is increasing interest in refining the indications for radiological examination and hospital admission of head injured patients. Guidelines currently available in the U.K. (1) prepared by a group of neurosurgeons help to rationalise the management of the more seriously head injured patient but are less helpful to the young doctor who is assessing the apparently minor injury. For example, they suggest radiography for all head injured patients who have scalp bruising or swelling. If applied to all patients attending Accident and Emergency (A & E) departments this would result in a significant increase in the skull radiography rate and hence in the cost of patient treatment (2). The guidelines do not clearly define the characteristics of those patients who require more careful assessment because of a greater risk of complications.

Despite the increasing interest in the biomechanics of head injuries in recent years most clinicians record little, if any, environmental information about the accident. It is assumed that a biomechanical assessment of injury cannot be used as a guide to management because recordable information would be inaccurate and could not be classified or ranked on a finite scale. However, work in primate models (3) has shown that the nature, severity and direction of forces applied to the head at different sites are all important determinants of the way the head responds and influence the type of brain injury sustained.

The aim of this study has been to attempt to correlate the biomechanical factors which are considered to be important in experimental head injury models with the clinical observations of patients attending an A and E department after head injury. It is suggested that such data might have potential prognostic value in identifying the small number of patients who are likely to sustain skull fractures or be at risk from the later development of intracranial complications.

METHOD

A retrospective analysis of every head injured patient attending the Salford Accident and Emergency service over a 12 month period was undertaken. The age, clinical status on arrival and details of management and outcome were noted. Any patient who had a history of a blow to the head, had sustained any form of scalp injury or had evidence of altered consciousness after a relevant injury was included in the survey. The "head" was defined as extending from the eyebrows to the occiput. Patients with isolated facial, nasal and eye injuries were excluded.

The clinical notes made in the Accident and Emergency Department and subsequent medical and nursing records were examined. Details of age, sex, delay in presentation, source of referral, place of incident and mode of arrival were noted. Relevant features of the clinical assessment were recorded - viz Glasgow Coma Score on arrival, occurrence of fits, clinical evidence of basal skull fracture, focal neurological signs, the occurrence of headache or vomiting and the duration of post traumatic amnesia. The interpretation of skull radiographs and initial management was noted and the subsequent progress of all patients checked. The Registrar Generals records of head injury related deaths in the Salford District were obtained to ensure the completeness of the data on fatalities.

An assessment was made of the speed of any impact to the head, the site of that impact and the object (if any) with which the head collided. Table 1 defines the various parameters used. This information was collected by one of us (J.M.H.) who was not involved in clinical management.

The results were analysed on the Prime 9955 computer using the Statistical Package for the Social Sciences (4).

TABLE 1
Guidelines for Classifying Biomechanical Data

SPEED OF IMPACT:

HIGH:-	Collision of two fast moving objects Assault by thrown or falling object Fall > 2 metres Pedestrian hit by car Strike by golf club or hockey stick
MEDIUM:-	Fall from standing position Assault by human contact Running speed collision with stationary object
LOW:-	Walking/Trip speed collision with stationary object Fall < 1 metre

CONTACT AGENT

SHARP:-	Surface area < 5 cm sq e.g. edge of furniture or glass, cricket ball, hammer.
BLUNT/HARD:-	Surface area > 5 cm sq onto concrete, flat glass, rough ground, "bone".
BLUNT/SOFT:-	Surface area > 5 cm sq onto grass, carpet, softball, "flesh".

RESULTS

During the 12 month period over 60,000 patients attended the two A and E departments in Salford (population 290,000) and 5469 satisfied the criteria for admission to the survey. Table 2 contrasts the estimated speed of impact with the length of post-traumatic amnesia (PTA). 44% of the patients were considered to have sustained injury at low speeds and of these only 1% were amnesic for more than 5 min. In contrast, of the 9% who were involved in high speed impacts, 20% had a PTA of more than five minutes. There was a consistent trend of longer PTA at higher speeds which was highly significant ($p < 0.001$).

TABLE 2
Relationship between Duration of Post-Traumatic Amnesia and Speed of Impact
n = 4826

SPEED OF IMPACT	Totals	POST-TRAUMATIC AMNESIA Nil	Transient	< 5 min	> 5 min
*** LOW	2024	1919 (95)	59 (3)	31 (2)	15 (1)
MEDIUM	2311	1850 (80)	207 (9)	135 (6)	119 (5)
*** HIGH	491	289 (59)	46 (9)	58 (12)	98 (20)

Figures in brackets = row %
*** Chi^2 $p < 0.001$

Table 3 contrasts the duration of PTA with the contact agent. Patients who had been struck by sharp objects had significantly ($p < 0.001$) less post-traumatic amnesia. Only 3% were amnesic, in contrast to 15% of those who impacted against blunt/soft objects and 20% of those involved in blunt/hard contact. There was no significant difference between those impacting against blunt hard and blunt soft surfaces.

TABLE 3
The Relationship between Duration of Post-Traumatic Amnesia and Contact Agent
n = 4806

	CONTACT AGENT	Total	POST-TRAUMATIC AMNESIA Nil	Transient	< 5 min	> 5 min
NS (BLUNT/SOFT : BLUNT/HARD)	BLUNT/SOFT	144	122 (85)	9 (6)	4 (3)	9 (6)
*** (BLUNT/HARD : SHARP)	BLUNT/HARD	3556	2854 (80)	290 (8)	202 (6)	210 (6)
	SHARP	1106	1070 (97)	10 (1)	15 (1)	11 (1)

Figures in brackets = row %
*** Chi^2 $p < 0.001$
NS Not significant

When the duration of PTA was correlated with the site of the impact (Table 4) no difference was found between the parietal, temporal and occipital areas. However frontal impacts were associated with a significantly shorter duration of PTA than impacts elsewhere. 9.5% of patients in whom there was no evidence of impact had a PTA over 5 minutes. This contrasts with 4.9% for those in whom there was skull contact ($p < 0.001$).

TABLE 4
The Relationship between the Duration of Post-Traumatic Amnesia and the Site of the Impact

SITE	POST-TRAUMATIC AMNESIA Nil	Transient	< 5 min	> 5 min
1. FRONTAL	2077	146	85	100
2. PARIETAL	883	55	44	64
3. OCCIPITAL	885	98	73	70
4. TEMPORAL	419	35	32	36
5. TOTAL WITH IMPACT (1-4)	4264	334	234	270
6. NO EVIDENCE OF IMPACT	278	41	32	37

Chi^2 tests:
1:2 $p < 0.05$
1:3 $p < 0.001$
1:4 $p < 0.001$
5:6 $p < 0.001$

An examination of the incidence of bony injury at various scalp contact sites showed that vault fracture was more common in the temporal region (5.3%) and less so in the parietal (4.5%), occipital (3.4%) and frontal regions (1.3%). Table 5 compares the incidence of skull fracture at different speeds of impact. 11.3% of fast impacts were associated with skull fracture compared with 0.16% of slow impacts. The notes of the four patients identified in Table 5 who sustained vault fractures in low impact speed accidents were further examined. Three were young children and the fourth an intoxicated youth. The determination of impact speed in these cases may be unreliable as the clinical notes indicated that the injuries were not consistent with the history. The positive correlation between speed and incidence of fracture was maintained at each scalp contact site.

TABLE 5
The Incidence of Skull Fracture at Different Speeds of Impact
n = 5336

SPEED OF IMPACT	NO FRACTURE	FRACTURE (%) PRESENT
LOW	2386	4 (0.16)*
MEDIUM	2384	50 (2.10)
HIGH	460	52 (11.3)

$Chi^2 = p < 0.001$
*These cases are described in the text

DISCUSSION

Most head injured patients seen in the A & E department do not appear to have sustained serious brain injury. They will usually present with minor degrees of cerebral concussion corresponding to Gennarelli's grading I-III[5]. Whilst not producing life threatening paralytic coma or prolonged traumatic unconsciousness, the resulting confusion and amnesia may be clinically and socially significant. Numerically it accounts for much of the morbidity associated with traumatic brain injury in the general population.

The duration of post-traumatic amnesia is generally considered to be the best single yardstick for the assessment of severity of a head injury[6]. Presence of a skull fracture has also been used to indicate severity. Whilst not itself a cause of neurological deterioration it does alert the clinician to the risk of complications[7].

Biomechanical data may be additional sources of information. A mechanistic approach to the study of head injury has been developed in animal models by Gennarelli et al[3]. Their experients show that most clinical forms of observed brain injury can be reproduced by accelerating the head (irrespective of whether the head has received a direct blow). In contrast, extradural haematomata complicating vault fracture are always produced by direct scalp contact forces and are not influenced by inertial forces.

In our study PTA over 5 minutes was much more common in patients sustaining injury at high speed (Table 2). Skull fracture was also more common at high impact speeds (Table 5). In contrast, patients who sustained sharp frontal impacts had shorter periods of amnesia (Tables 3 and 4). More patients had a PTA over 5 min when subjected to impulsive loading forces without scalp contact than when the scalp was directly injured (Table 4).

These clinical findings are based on a rather imprecise retrospective analysis of case notes yet they do appear to support the laboratory results of Gennarelli. A prospective study linking careful analysis of loading forces with observed patterns of head injury is planned.

The collection of more precise biomechanical data in the A & E department should be encouraged as it could provide more discriminating factors for the clinician to use in the initial assessment of the head injured patient.

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