HEAD INJURY EVALUATION: CRITERIA FOR ASSESSMENT OF FIELD, CLINICAL AND LABORATORY DATA

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ABSTRACT

In this paper, an attempt has been made to provide guidelines for comparison of field, clinical and laboratory data on head injury. Difficulty in comparison arises due to the differing nature of the information that is produced in each type of investigation. Unconsciousness, dizziness, and loss of memory play an important role in determining the AIS code for an actual accident victim, but it is difficult to determine this kind of information from experiments on non-human primates. In the case of cadaver experiments, such information is not available at all. Details of internal brain injuries are not available for accident victims except those injured fatally and autopsied. On the other hand, in laboratory experiments on animals and cadavers, information on internal injuries can be obtained. These differences are discussed further and a guideline is proposed for interpreting injury data from different sources. An alphabetical list of head injuries is included along with AIS ratings for each injury. A methodology is proposed for evaluating multiple head injuries.

IT IS WELL KNOWN that head injuries are a major cause of death in automobile accidents, but head injury mechanisms are still not very well understood. The reasons for this are many: the relative contribution of linear and angular accelerations in head injury are not known; it is difficult to describe the structural and material properties of the intact head for detailed modeling; the mechano-pathological reasons for headaches, unconsciousness, dizziness and loss of memory are not known; and it is very difficult to compare injury data produced by different teams. It is this last problem which will be discussed in detail in this paper.

There are innumerable problems involved in comparing data produced by accident investigators, pathologists and laboratory researchers as not only are their evaluation techniques often very different but also their perceptions of the same injury may vary considerably. With the establishment of the Abbreviated Injury Scale (AIS) by the American Medical Association (1)*, some uniformity has been established in rating injuries, but some basic problems remain. Headache, dizziness and concussion play an important role in determining the AIS code for accident victims, but it is difficult to get this kind of information from experiments on non-human primates

* Numbers in parentheses designate references at end of paper.

and human cadavers. It is almost impossible to determine headache or dizziness conditions in animals, and even accurate determination of the state of consciousness is very difficult. This is further complicated by the fact that return of awareness to stimuli usually precedes motor and sensory recovery which in turn recover before restoration of memory and other cognitive functions (2). Since all experiments are done with animals under anesthesia, it becomes even more difficult to determine the state of consciousness. Ommaya (2) has reported a technique (Sensory Evoked Response) of monitoring the state of consciousness, but since this has not been widely used, it is difficult to assess its usefulness. Under the best of circumstances, use of animal models for predicting human injury is a difficult procedure. The number of unknowns in such work precludes completely definitive studies. Even more difficult is the prediction of long term effects of head trauma. In a longitudinal study on the post-traumatic symptoms in head-injured veterans of the Korean war (3), long term after effects such as headaches, dizziness, disorders of movement, nervousness and irritability, loss of memory, and intolerance to alcohol were reported. It is clear that such long term observations on animals require prior training, are difficult to detect, and the whole process is prohibitively expensive for most research groups.

In order to make clinical correlations between experiments and real life situations, both engineers and physicians must understand the strong points and shortcomings of each other's work. Lindgren, et al. (4) have described the effects of impacts on different locations and some clinical-mechanical correlations, but such information has to be more definite and exhaustive for accident investigators to reconstruct the occupant kinematics. Head injury data is basically obtained from three sources: (a) accident investigations, (b) animal tests, and (c) human cadaver tests. The nature of the information from each source is described below:

(a) Accident Investigation: Occupant kinematics are reconstructed from evidence such as occupant's bruises, vehicle damage, post-accident position of occupant, direction of impact, estimated velocity of impact and interviews when possible. This reconstruction varies greatly in its accuracy, especially with respect to the velocity of head impact. For minor and moderate head injuries, the information is usually sketchy and mainly about behavioral symptoms. For serious injuries there are more details of external injuries recorded and very little information about internal injuries. It is only when the injuries are fatal and an autopsy is performed, that detailed information about internal injuries is recorded. These constraints can bias the information base towards the more serious injury levels.

(b) Animal Tests: These tests can provide accurate information on kinematics, forces generated, and pathological injuries, both external and internal. However, there is very little behavioral information except estimates of state of unconsciousness. The effects of anesthetizing drugs are not very well known. It is difficult to obtain long term information and still comply with animal use guidelines. Brain damage not accompanied by tissue or vascular damage is difficult to assess. Correlations between animal trauma and human trauma are not very well documented in most cases.

(c) Human Cadaver Tests: Like animal tests, there is usually detailed documentation on the kinematics of impact. In most cases, the cadavers have been dead for more than three days and the blood changed in composition and drained to the lowest areas. Lack of vascular pressure and muscle tone also make the experiment more "unlifelike." Recently, experiments have been done after pressurizing the vascular system, but how much of this affects the experiment is still not clear. Black ink has been mixed with the pressurization fluid to detect impact-produced injury (5). There is no behavioral information produced and only the gross tissue and vascular damage is usually detected. The main advantage of these experiments over animal experiments is that the anatomical structures are the same as in the living human. Changes of tissue properties in the post mortem state, particularly soft tissues, can introduce modifying factors in test data, however.

Keeping all of the above points in mind, guidelines for head injury assessment, especially in the laboratory, are suggested in the following sections and a method for evaluating head injury in terms of AIS codes has been outlined. These are preliminary studies in the area and must be refined and changed through active discussion among all researchers connected with head injury evaluation. Some typical examples of three types of injury descriptions (accident investigation, animal and human cadaver tests) are given in Table 1.

HEAD INJURY EVALUATION

ASSIGNING AIS CODES - As discussed above, behavioral and neurological injuries are difficult to detect in animal experiments and are non-existent in human cadaver experiments. Due to this, it is very difficult to assign AIS codes to animal injuries. An AIS code of 1 (6) can be given if the head impact results in headache or dizziness. Therefore in animal head impacts, when there are no external or internal signs of injury, one does not know whether to assign an AIS code of 0 or 1. Similarly, the difference between AIS 2 and AIS 3 for "cerebral concussion with or without skull fracture," is that the former is assigned when unconsciousness lasts for less than 15 minutes and the latter for more than fifteen minutes. In both cases, the injury must not be accompanied by any severe neurological signs, otherwise the injury should be rated as AIS 4. As discussed earlier, it is very difficult to accurately determine the state of consciousness in anesthetized animals. As such, it is quite easy for the investigator to give an AIS 2 rating when it should actually be 3. Similar arguments can be made for any injury level. Therefore, when evaluating results of animal experiments on head injury, it must be kept in mind that the assigned AIS codes could be underestimates unless specifically mentioned by the investigator. This would be even more the case for human cadaver experiments. One alternative is to give a "double" coding whenever in doubt; e.g., if the injury is described as "left-zygomatic arch fracture, scalp laceration (deep and extensive) over left temporal bone," then it would be safe to call it an injury with AIS of 2/3, because from accident studies, these types of injuries are usually accompanied by unconsciousness. In this manner, the readers of the report would be immediately made aware of the ambiguity of the situation and thus cautioned to use the AIS rating more realistically with minimal biasing of their results.

ASSESSING MULTIPLE INJURIES - The second difficulty in assessment of head injury arises when there are multiple injuries. The cumulative result of multiple injuries is extremely difficult to assess and usually is done quite subjectively. In a recently published study by Baker et al. (7) a method is described by which the overall injury severity can be evaluated for patients with multiple injuries in different body regions. In this study, medical examiner data for more than two thousand persons was examined and death rates of the victims correlated with various combinations of their AIS scores. It was discovered that if the AIS scores for the three most severely injured different body regions are squared and added for a victim with multiple injuries, the resultant score (the Injury Severity Score (ISS)) has the highest correlation with death rates than any other criterion tested. This indicates that more serious injuries have a higher weighting than less serious injuries in different body regions as far as mortality is concerned. This score was developed for determining an overall score for multiple injuries in different body areas, whereas the main problem under consideration in this paper is the determination of an overall AIS code for a single body region, the head, with multiple injuries.

Appendix A contains an alphabetical list of injuries commonly observed in the head and ratings of these injuries based on the AIS definitions of injury (minor = 1, moderate = 2, severe (not life threatening) = 3, severe (life-threatening, survival probable) = 4, critical (survival uncertain) = 5, maximum severity injuries (currently untreatable) = 6). It is important to note that this is a preliminary attempt and readers must communicate with the authors if they disagree with any of the ratings. In single body regions like the head, the AIS score is usually assigned quite subjectively, according to the most severe injury in the region. This is effective in many cases since the most severe injury is quite often the most important one and usually the main cause of impairment or death. A problem can arise in cases of multiple severe injuries especially when there are multiple injuries at AIS 3 and AIS 4 level. Since multiples of the more severe injuries are very important in a single body region, they should be weighted heavily. In addition to exhibiting a weighting effect, it would be quite useful to research investigators making data comparisons if a multiple injury scoring system can be reported in terms of the AIS codes (i.e., an AIS 3 level injury and an AIS 4 level injury in the same region should be combined to produce a rating somewhere between an AIS 4 and an AIS 5 level of overall injury). The use of the technique of squaring the AIS codes of the various injuries in a single body region and summing the resulting values (as is done in the ISS technique for various body regions) but then taking the square root of that sum appears to produce too great a weighting factor and does not produce the desired result of ratings that are reportable in terms of AIS codes. After experimenting with various techniques for combining the individual AIS codes it was found that the cube root of the sum of the cubes of the codes seemed to satisfy the requirements for weighting multiple injuries at an appropriate level while maintaining an overall rating consistent with the AIS code range of 1 to 6.

Table 2 lists the results of applying both the square and cube techniques to the AIS codes for all of the injuries listed for the examples in Table 1. Examination of the results for both techniques and comparison with the ratings of the accident investigators where applicable indicates the utility of the cube method. This method can only be considered a tentative approach to a complex problem, but its success in allowing reasonable overall injury level rating in the case of multiple injuries to the head is encouraging.

SUMMARY

It is very difficult to compare head injuries produced in real life accidents, animal experiments and human cadaver experiments. Researchers must be very aware of the shortcomings of each source of information before attempting any extrapolation. Since it is difficult to obtain information about neurological or behavioral damage from head impacts on animals and impossible in the case of human cadavers, it is suggested that head injuries should be reported in great detail and wherever ambiguity exists to use a "double" scoring system for assigning an AIS number (e.g., AIS 4/5). In the case of multiple head injuries, an overall AIS number for the head can be obtained by taking the cube root of the sum of all AIS scores cubed. This seems to provide a good correlation between multiple head injuries and an overall head AIS rating.

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TABLE 1. DESCRIPTION AND USE OF AIS RATINGS FOR ROAD ACCIDENT ANALYSIS, CADAVER TESTS, AND LOWER PRIMATE TESTS

CASE IDENTIFICATION & INJURY LOCATION	INJURY DESCRIPTION	AIS
BU-71007-1 Face	Right Cheek - Abrasions (Bruises or Contusions)	1
	Left Cheek - Abrasions	1
	Chin - Laceration 3.5 x 1.0 cm (Severe)	2
	Nose - Comminuted Fracture	3
	Maxilla - Comminuted Fracture	3
	Left Zygoma - Comminuted Fracture	3
	Mandible - Comminuted Fracture	3
	Teeth Dislocation	1
Skull	Right Parietal Bone - Simple Fracture	2
	Right Temporal Bone - Simple Fracture	2
	Right Basilar Fracture (Simple)	3
Brain	Subarachnoid Hemorrhage (Most of Brain) +1	4+1
AA-00306-2 Face	Nose - Laceration	2
	Left Zygoma - Compound Fracture	3
Skull	Scalp Right Side - Laceration	2
	Three Basilar - Fracture 2 Simple, 1 Depressed	4+1
	Right Temporal - Fracture	
Brain	Dura - Tear	3
	Subdural Hemorrhage	4
Cadaver 20185-064 Skull	Scalp Left Side Temporal Hematoma	2
Brain	Bridging Veins Hemorrhage	3
	Subarachnoid Bleeding Posterior Frontal Lobe	4
	Left Temporal - Parietal Subdural Hemorrhage	4
	Right Temporal - Parietal Subdural Hemorrhage	4

TABLE 1. DESCRIPTION AND USE OF AIS RATINGS FOR ROAD ACCIDENT ANALYSIS, CADAVER TESTS, AND LOWER PRIMATE TESTS (Continued)

CASE IDENTIFICATION & INJURY LOCATION	INJURY DESCRIPTION	AIS
Cadaver 20117-041		
Skull	Occipital Fractures Simple (+1)	3
Brain	Dura - Tear	3
Primate Type II 014		
Skull	Occipital - Depressed Fracture (+1)	3+1
	Temporal - Simple Fracture	2
	Basalar - Compound Fracture	3
Scalp	Occipital - Contusion	1
Brain	Occipital - Subdural Hemorrhage (+1)	4+1
	Occipital - Laceration	4
	Dura - Tear	3
	Dead on Impact	-
Primate Type II 018		
Brain	Cerebral Concussion > 15 min. Unconsciousness	3
	Parietal Lobes Subdural Hemorrhage	4

TABLE II. APPLICATION OF MULTIPLE INJURY ASSESSMENT

CASE IDENTIFICATION & INJURY LOCATION	$\sqrt{\sum(AIS)^2}$*	$\sqrt[3]{\sum(AIS)^3}$*	INVESTIGATOR'S OVERALL INJURY AIS
BU-71007-1			
Face	7 (6.6)	5 (4.9)	4
Skull & Brain	6 (6.5)	6 (5.6)	6
AA-00306-2			
Face	4 (3.6)	3 (3.3)	3
Skull & Brain	7 (7.3)	6 (6.1)	6
Cadaver 20185-064 Skull & Brain	8 (7.8)	6 (6.1)	6
Cadaver 20117-041 Skull & Brain	4 (4.2)	4 (3.8)	4
Primate Type II - 014 Skull & Brain	9 (8.9)	7 (6.8)	6
Primate Type II - 018	5 (5.0)	5 (4.5)	5

* Actual number in parentheses accompanied by that number rounded to the nearest AIS.

APPENDIX A

AIS INJURY SCALE DICTIONARY

INJURY AREA	INJURY DESCRIPTION	AIS
Brain		
Frontal Lobe		
Occipital Lobe		
Parietal Lobe		
Temporal Lobe		
	Avulsion	6
	Epidural Hemorrhage*	3
	Highly Localized and Focussed Injuries; on/in the Tissue, e.g., Contre-Coup	3
	Intraventricular Extravasation of Blood Into the Ventricular Space*	3
	Laceration/Puncture	4
	Subdural Hemorrhage*	4
	Tear to Major Vessels; Superior Sagittal Sinus, Middle Cerebral, Post Cerebral, etc.	5
	Cerebral Concussion	
	Headache, Dizzyness, Dazed	1
	Less Than 15 Min. Unconscious	2
	Greater Than 15 Min. Unconscious Without Severe Neurological Signs	3
	Greater Than 15 Min. Unconscious With Severe Neurological Signs	4
	Greater Than 24 Hrs. Unconscious, Intracerebral Clot	5
	Greater Than 24 Hrs. Unconscious	5
Cerebellum	Hematoma	4
	Intracerebellar Hematoma	5
Medulla Pons	Avulsion	6
	Contusion	5
	Cruse	6
	Laceration	6
Dura	Tears or Leaks	3
	* (If extensive add one)	
Cheeks	Abrasion	1
	Contusion, Bruises	1
	Laceration	
	Deep/Extensive	2
	Nerves/Vessels Involvement	3
	Severe Hemorrhage	4
	Superficial	
	Zygoma	
	Fracture Comminuted	3
	Fracture Simple	2

INJURY AREA	INJURY DESCRIPTION	AIS
Chin	Abrasion	1
	Contusion, Bruises	1
	Laceration	
	Deep/Extensive	2
	Nerve/Vessel Involvement	3
	Severe Hemorrhage	4
	Superficial	1
	Mandible	
	Fracture Comminuted	3
	Fracture Simple	2
	Temporo-Mandibular Joint Involvement	2
	Maxillary	
	Fracture Comminuted	3
	Fracture Simple	2
	Teeth	
	Broken/Loose/Loss Of	1
Ear	Ear Canal Injury	1
	Inner Ear Injury	
	Deafness or Vertigo in One Ear	2
	Deafness or Vertigo in Both Ears	3
	Ossicular Chain Dislocation	2
	Pinna (Outer Ear)	
	Abrasion	1
	Avulsion One Ear	2
	Avulsion Both Ears	3
	Contusion	1
	Laceration	1
	Laceration, Severe	2
	Tympanic Membrane Rupture	2
Eyes	Avulsion	3
	Canaliculus Laceration	1
	Choroid Rupture	1
	Conjunctiva	
	Abrasion	1
	Laceration	1
	Cornea	
	Abrasion	1
	Foreign Body	1
	Laceration	2
	Enucleation of One Eye	2
	Enucleation of Both Eyes	3
	Iris Detachment	1
	Lid	
	Abrasion	1
	Avulsion	2
	Contusion	1
	Extraocular Muscle Paresis/Paralysis	2
	Laceration	1
	Optic Nerve Avulsion	3
	Orbit	
	Fracture Comminuted	4
	Fracture Simple	3
	Retina	
	Detachment	2

INJURY AREA	INJURY DESCRIPTION	AIS
Eyes (Cont.)	Retina (Cont.)	
	Edema	1
	Hemorrhage	1
	Laceration	1
	Sclera	
	Laceration	2
	Rupture	2
	Vitreous Hemorrhage	1
Nose	Abrasion	1
	Contusion	1
	Ethmoid	
	Fracture Comminuted	3
	Fracture Simple	2
	Nose	
	Fracture Comminuted	3
	Fracture Simple	2
	Sphenoid	
	Fracture Comminuted	3
	Fracture Simple	2
Scalp	Abrasion	1
	Contusion	1
	Hematoma	2
	Laceration	
	Deep/Extensive	2
	Superficial	1
Skull Fractures		
Frontal		
Occipital		
Parietal		
Temporal		
	Fracture Comminuted*	3
	Fracture Compound*	3
	Fracture Expressed*	3
	Fracture Simple*	2
	Separation of Cranial Bones At Sutre	3
Basilar		
	Fracture Comminuted	4
	Fracture Compound	4
	Fracture Expressed	4
	Fracture Simple	3

*(If More Than Two Fractures of the Same Bone Add One)

Parts of tha above dictionary are taken from Ref. (6).