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RESEARCH ARTICLE

ROLE OF AN EXPERT SYSTEM IN MANAGEMENT OF HEAD INJURY PATIENTS

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ABSTRACT

Objective: The objective of our study is to develop an expert system for Management of Head Injury Patients (MHIP) to automate treatment planning support for severe head injury patients.
Methods: A study was conducted among the Head injury Patients of Government General Hospital (GGH), Chennai, India. The necessary information were recorded and the risk factors were identified by various multivariate statistical models using SPSS package, with all these information together with the opinion of the Neurosurgeon on important clinical factors an Expert system MHIP has been developed.
Results: Our study reveals that out of 801 head injury cases, 261 were severe head injury cases (GCS ≤8). It was alarming to observe that around 60% of the severe head injury cases were dead. Risk of Persistent Vegetative State /Death is 2 (95% CI = 1.18 - 4.33) times more in older people than the younger ones. The cases with abnormal respiratory rate had 5 (95% CI = 2.54 - 8.40) times more chances for death than cases with normal respiratory rate of 10-24/min. Thus the older age (P=0.001), abnormal respiratory rate (P=0.003) and lower GCS (P=0.008) were found to be consistent risk factors and significantly associated with the mortality of severe head injury patients.
Conclusion: From the perspective of patients' well being, Persons trained in trauma care in the rich industrialized countries depend a great deal on expensive, sophisticated diagnostic and curative equipment and materials. It will not be possible for most hospital in Low income Countries to obtain and stock such equipment and materials. Therefore an **E**xpert system MHIP, developed in our study would help the neurosurgeon to a greater extent in identifying the patients, whose life can be saved, and which are cost-effective and feasible in such Institutions.

INTRODUCTION

Head injury is a crucial worldwide public health problem. It accounts for one third of Trauma deaths and for a much large proportion of lifelong disability after trauma. The associated outcomes after severe head injury include disability or death for the grievously injured (Marshall *et al*., 1991a,1991b), and marked disruption of the lives of their family members due to the high costs in terms of lost work and wages, increased medical bills, legal fees and frequent transportation's charges (Brooks DN, 1991). In the United Kingdom (UK) there are half a million-trauma admissions per year and 14,500 of these die (Court-Brown CM, 1990). Trauma is the most common cause of death under the age of 35 years in most developed countries and head injury is the commonest cause of these accidental deaths (Gennarelli TA *et al*., 1989). Another study reported that Head Injury results in a million patients attending Accident and Emergency departments in the UK, leaving more than 5000 dead and 1500 with permanent brain damage each year (Jennett B, 1986). Injuries involving some type of blow to the head are most common in our society. Head injuries can range from relatively minor damage to the scalp and face such As lacerations, abrasions and bruising to more serious consequences involving damage to the brain. While traumatic brain injury occurs much less frequently, it is important to know how it is identified and what to do for the person. The management of severe head injury patients is of prime importance in to-day's neurosurgical practice. After severe injuries, the question is whether or not the patient will survive, and if he does, what is the likelihood of persistent disability. The consequences of this uncertainty are that the management of head injuries depends more on intuition than on logical based decisions. It will also be necessary to device a simple means for calculating predictions at the bedside on individual patients.

Consulting charts or probability tables or computer programs will greatly assist doctors in predicting reliably and accurately. This has led to an interest in developing better monitoring and treatment methods to minimize any potential for secondary injury and to present the Neurosurgeon with a patient who is alive and has a good chance of good survival. The quality of a medical treatment is primarily based on two factors: the quality of the treatment decision and the quality of the outcome that follows the decision. The quality of the decision depends on the Neurosurgeon's ability to discern the parameters influencing the problem, to establish the domain relationship

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among the parameters and to rank the parameters according to their importance. The Neurosurgeon tackles all these issues, and suggests the optimal treatment. If needed, the Neurosurgeon provides the secondary treatment also. However, it is not always possible to have the Neurosurgeon around when an emergency arises. Hence, it would be of tremendous help if the Neurosurgeon's knowledge could be transferred to an Expert system that could be queried in the case of emergency. As statistical techniques have become more sophisticated and the interface between the clinician and the statistician has become better developed, an enlarging repertoire of statistical methods for obtaining a prognosis has become available. An important application of numerical methods to determine the prognostic significance of clinical factors is to pin down in order of severity those factors associated with a poor-prognosis.

Table 1. Study subjects

Number	
Total patients with head injury	801
Glasgow coma scale score ≤ 8	261
Glasgow coma scale score > 8	540

Table 2. Outcome in the study subjects with Severe head injury and Mild head injury

Outcome	GCS	
	≤ 8	> 8
Poor Outcome		
Death	157	98
PVS	1	2
Good Outcome		
Severe Disability	16	15
Mild Disability	25	61
Good Recovery	62	364
Total	261	540

Such factors may provide important information regarding expected outcome. However, prediction for an individual patient will generally have higher degree of accuracy and reliability if they are based on combined scores of two or more features. This will lead to the identification of those combinations of factors that indicate that a certain therapy is required, if results are to be improved. Studies have shown that when clinical features are well selected, the independence model performed well better than more complex techniques and gave predictions that were more consistent and reliable than those made by senior neurosurgeons. This paper deals with management of patients with severe head injury and presents a computer-based statistical approach to manage the patients with head injury. The study takes into account the ideas and methods of statistics and expert system to show how a formal analysis of head injury patients can provide valuable information regarding the factors which are associated with the outcome of severe head injury patients.

MATERIAL AND METHODS

The study was carried out in the Department of Neurosurgery, Madras Institute of Neurology, Government General Hospital (GGH), Chennai, India. A structured proforma was designed to incorporate all the variables which were found to be statistically significant by various multivariate statistical models such as Log-linear, Logistic regression, Survival analysis and important clinical factors based on the opinion of the Neurosurgeon, an Expert system MHIP (Management of Head Injury Patients) has been developed with the help of Visual basic, to provide the clinician a prognostic guideline on severe head injury patients for priority care. The following information was collected from patients suffering from Head injury: Socio Demographic Factors ,Clinical parameters like Loss of Consciousness (LOC) < 1 hour, (LOC) > 1 hour,

Table 3. Intra Cranial Pressure (ICP) of severe head injury patients

ICP Admission	ICP after a week													
	Dead			< 15		15-25			26-35		>35		
	ICP after Two days			ICP after Two days		ICP after Two days			ICP after Two days		ICP after Two days		
	<15	26-35	>35	< 15	15-25	< 15	26-35	15-25	26-35	15-25	26-35	>35	15-25
<15	100	14.28	16.67	98.0	100	50	100	4.5	25	100	25	20	100
15-25		71.43	66.67	91.91		50		90.90	56.25		50	40	
26-35		14.29	16.67					4.5	18.75		25	40	
>35													
Overall	.41	1.4	1.2	84.9	2.6	.41	.20	4.5	3.2	.70	1.6	1.0	.20

Table 4. Association between Level of consciousness and Mode of Injury in different age Group

Age Group	Mode of injury										
	Assault			Road Traffic Accident			Fall			Train Traffic Accident	
	LOC			LOC			LOC			LOC	
	< 1 hr	> 1 hr	No loss	< 1 hr	>1 hr	No loss	< 1 hr	>1 hr	No loss	< 1 hr	>1 hr
<=10	5.33	1.33	0.79	22	10	2	44	18	2	2	2.66
11-20	8.66	3.15		37.3	21.33	5.33	10.66	14.66	1.33	5.33	5.51
21-30	8.9	3.96		31.5	24.41	0.99	15.75	3.94	0.79	3.15	1.98
31-40	5.80	2.89		38.6	21.78	4.35	14.85	5.94	0.99	0.99	2.89
41-50	1.41	8.45		37.6	27.54	2.82	4.35	10.14	1.45	2.89	1.41
>=51				22.5	35.21		12.68	9.86	4.23	1.41	

Table 5. Significance level of the factors considered for study

Factors	β	SE (β)	p-value	OR	95% CI for OR
GCS	0.314	0.118	0.008	1.37	1.09 to 1.73
Respiratory rate	1.084	0.370	0.003	2.95	1.43 to 6.09
Age	0.032	0.010	0.001	1.03	1.01 to 1.05
Obstructive Airway	0.482	0.363	0.184	1.62	0.79 to 3.30
Bleeding through throat	0.766	0.546	0.161	2.15	0.73 to 6.27
Muscular power	- 0.456	0.343	0.184	0.63	0.32 to 1.24
Type of Breathing	- 0.468	0.451	0.299	0.62	0.25 to 1.52
Pupillary reaction to light	0.221	0.334	0.509	1.24	0.65 to 2.40
Extra Ocular movement	0.108	0.260	0.677	1.11	0.66 to 1.85
Constant	-1.908	0.474			

Respiratory Rate, Clinical symptoms which includes Vomiting; Fits; ENT bleed; CSF leak and Alcohol intoxication, Neurological status such as Alert No focal Deficit (AND); Alert with Focal neurological Deficit (AFD); Impaired Consciousness No Lateralization (ICNL); Impaired Consciousness with Lateralization (ICL) and Deep Coma (DC). Intra Cranial Pressure (ICP) was grouped as follows: Group I: < 15 mm of Hg Group II: 15 – 25 mm Group III: 26 – 35 mm Group IV: > 35 mm. Glasgow Comma Score (GCS) is considered as Grou p I: Severe Head injury (3 – 8) Group II: Moderate Head injury (9 – 12) Group III: Mild Head injury (13 –15) and the Glasgow Outcome Scale (GOS): Death, Persistent Vegetative State (PVS), Severe Disability (SD), Mild Disability(MD) and Good Recovery(GR). Glasgow Coma score was recorded in 801 cases. Those individuals whose GCS ≤ 8 were considered as Severe Head Injury (SHI) patients and they were considered for the study.

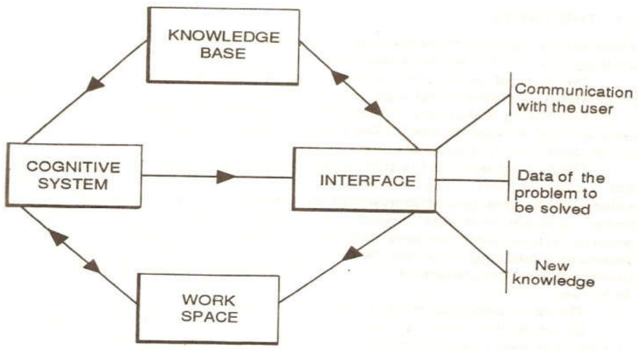

Fig. 1: Architecture of Expert System

Expert System

An Expert System is a knowledge-based computer program containing expert domain knowledge about objects, events, situations and courses of action, which emulates the process of human experts in the particular domain. In other words, expert system is a computer application that performs a task that would otherwise be performed by a human expert. Expert systems are extensively used in the medical field. Expert systems are a recent product of AI. They began to emerge as university research systems during the early 1970s. They have now become one of the most important innovations of AI. Expert systems had proved to be effective in a number of problem domains which normally requires the kind of intelligence possessed by a human expert. The areas of application are almost endless.

Architecture of Expert System

An Expert System consists of four modules. The knowledge base (Fig 1) stores the permanent knowledge of the domain of application and allows the system to act as an expert in the domain under consideration. It is especially this module which depends on the domain of the application. The cognitive system is the active element of the system; it simulates the activity of an expert in his/her deductive and explanatory capacity. The work space is the dynamic where the "reasoning" of the system is carried out. It is reset to zero for each work session, during which it gets modified. The interface is the module which allows acquisition of data and the dialogue with the users.

Applications of Expert System

Since the introduction of these early expert systems, the range and depth of applications has broadened dramatically. Applications can now be found in almost all areas of business, medical and government. The task force developing the guidelines for the management of severe head injury used a meticulous process relying on scientific evidence rather than expert opinion. In addition, the task force actively involved representatives of national and international medical societies and individuals with demonstrated expertise and interest in the care of patients with severe head injury. These guidelines address key issues relating to the management of severe head injury in adult patients with a Glasgow Coma Score of 3-8. They are by no means an exhaustive treatise on severe head injury. Due to the enormous effort required to develop evidence-based guidelines, the task force selected topics that were deemed to have an impact on outcomes in patients with severe head injury.

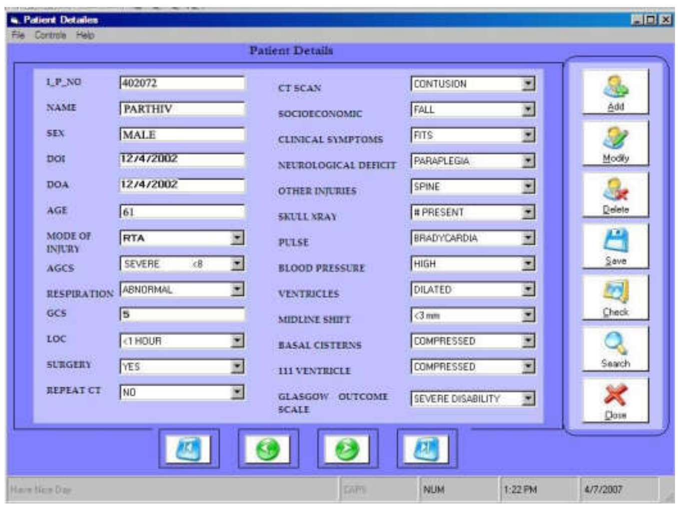

Fig. 2. Screen – shot highlights the patient details

Examples of such topics include indications for neurosurgical intervention, special consideration in pediatric head injury, the management of penetrating head injury and prognosis. The task force intent is that these guidelines will clearly state the current scientific basis for the clinical practice. For most

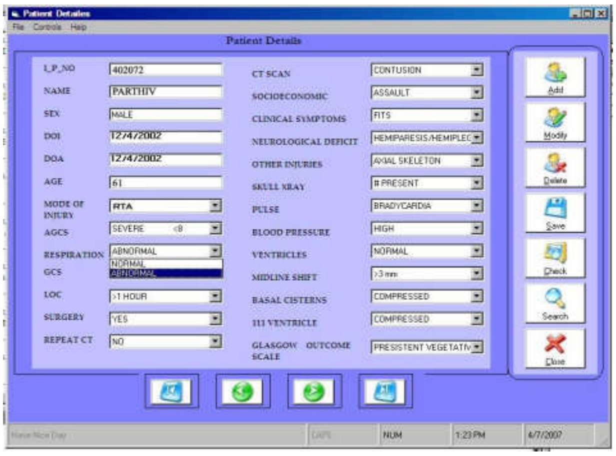

Fig. 3. Screen – shot highlights the options in Respiration

clinical practice parameters, scientific evidence is insufficient for standards of care, as is generally the case in most of current medical practice. Decision analytic approach to severe head injury management was adopted to automate the management process and analyzed the effectiveness and limitations of the decision analytic approach and presented a set of desiderata for effective knowledge acquisition in this setting. Head injury decision support system (HIDSS) combined experts' partial and uncertain knowledge for global decision-making. The integration is carried out such that the global uncertainty is minimal. The integrated knowledge is provided in form of a probabilistic rule base. The output of the rule base provides the optimal treatment in terms of patient recovery.

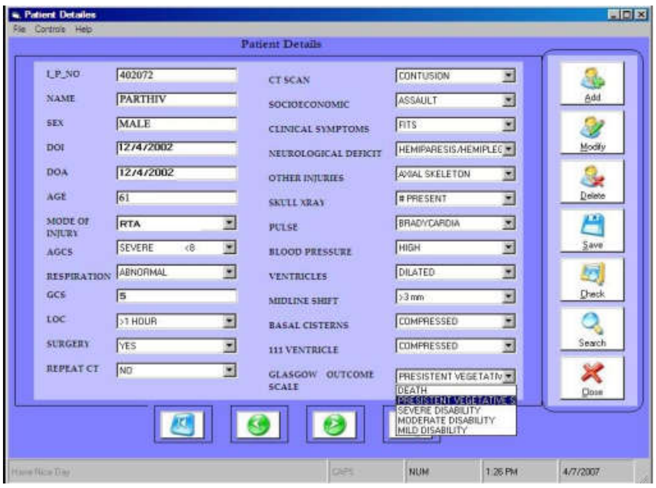

Fig. 4. Screen – shot highlights the Glasgow outcome scale (GOS)

The major objective of our study is to develop an expert system for Management of Head Injury Patients (MHIP) to automate treatment planning support for severe head injury patients. The MHIP provides automated guidelines for both consultation as well as educational purposes. Its primary purposes are:

- To assess the effectiveness of the various treatments available for a particular patient with severe head injuries.
- To suggest the treatment recommendations to the patient for a priority care.
- While choosing the prognostic factors and the treatments, experts' utilize two knowledge sources:
- The protocol used at the Neuroscience Intensive Care Unit.
- The trends observed by the neurologist in the course of the treatment.

One approach to design the MHIP is through the collection of deterministic if-then rules that relate the prognostic factors and treatments.

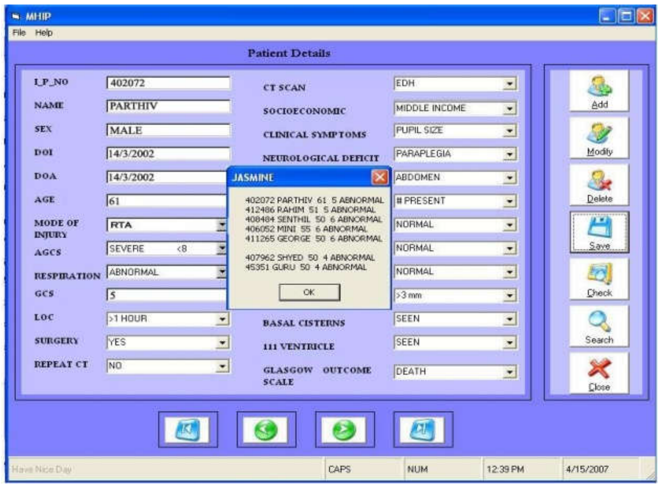

Fig. 5. Screen – shot of an Expert system MHIP shows the patients details and lists out the Patients for Priority care

RESULTS AND DISCUSSION

There were 801 head injury cases of which 261 were severe head injury cases (GCS ≤8) and 540 with mild head injury (GCS > 8) (Table 1). Out of 261 severe head injured cases, 157 were dead, 1 was in persistent vegetative state, 16 were with severe disability, 25 were with mild disability and 62 were with good recovery. Of the remaining 540 with mild head injury (GCS > 8), 98 were dead, 2 were in persistent vegetative state, 15 were with severe disability, 61 were with mild disability and 364 with good recovery (Table 2). Death and Persistent Vegetative State of the patients' outcome were combined together and considered as poor outcome of the patients. Good Recovery, Mild Disability and Severe Disability of the patients' outcome were combined together and considered as Good outcome of the patients. It was alarming to observe that around 60% of the severe head injury cases were dead. Our study reveals that out of the severe head injury cases, 254 were male with mortality rate of 38% and four of seven female were dead.

Half of the victims were due to Road traffic accident which had mortality in one out of every four cases. A small proportion (6%) was due to train accident and one third (33%) of them were dead. Twenty percent of the accidents were due to fall.14% individuals with head injury were due to assault. Among the Road Traffic Accident victims, Cyclist (29%) and Pedestrian (28%) were vulnerable to accident. Next group was the two wheeler motorist (16%) followed by pillion riders (5%). The occupants of the three wheeler or car or heavy vehicle accounted for 14%. ICP monitoring (Table 3) indicates that 88% patients belong to ICP-I (<15 mm of Hg), 5% belong to ICP-II (15-25 mm of Hg), 4% to ICP III (26-35 mm of Hg) and 3% to ICP IV (>35). Association between loss of consciousness and mode of injury in different age groups (Table 4) indicates that more than two-fourth of patients is victim of road traffic accidents. An overall examination of loss of consciousness and mode of injury reveals that 93% of patients who have experienced loss of consciousness are over the age of 50. Statistical analysis of our study reveals that of the 261 severe head injury patients, 69 (27%) cases with the age of above 50 years, the risk of PVS/D is 2 (95% CI=1.18 - 4.33) times more in individual above 50 years than the individual below 50 years. Forty three percent of the individuals had abnormal respiratory rate i.e. Less than or equal to 9 or more than or equal to 24/min, in severe head injury. The cases with abnormal respiratory rate had 5 (95% CI =2.54 - 8.40) times more chances for death than cases with normal respiratory rate of 10-24/min. The results obtained in the study are specific to the outcome of severe head injury patients and the conclusions may differ for moderate and mild head injury patients. The study has derived a set of variables and reduced the list of potential predictors to a minimal one. The confirmed potential predictors: older age, lower GCS and abnormal respiratory rate could be easily monitored even by hospital support staffs to estimate the probability of outcome following severe head injury and present the neurosurgeon a patient who is prone to a high risk of mortality for priority care and whose life can be saved, at the same time which are cost-effective using an expert system MHIP.

Severe head injury involves damage to the brain. The immediate effects of the head injury often results in a number of related problems, such as loss of income, loss of friends, loss of intimacy and the loss of freedom. The most common causes of severe head injuries are motor vehicle accidents and these accidents takes place due to the carelessness and a speed driving, therefore policy makers should take steps to educate people to avoid the accidents.. The traumatic head injury usually has debilitating consequences ranging from a mild disability to a vegetative survival and death. An Expert system MHIP would be useful in identifying patients (Fig 2 - 5) who have a reasonable probability of survival. Given a patient state, the purpose of the MHIP is to list out the patients according to their severity for priority care. Statistical techniques had identified (Table 5) that the most consistent risk factors for mortality are older age (P=0.001), low Glasgow coma score (P=0.008) and abnormal respiratory rate (P=0.003) among severe head injury patients and are found to be statistically significant. Hence those patients, who are older, having low Glasgow coma score and abnormal respiratory rate, either singly present or in combination should be given priority for treatment and an expert system MHIP will list out such patients and the maximum effort can be devoted to their care.

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