A COMPUTER BASED STATISTICAL APPROACH IN MANAGEMENT OF SEVERE HEAD INJURY PATIENTS

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ABSTRACT

The paper outlines the modeling approach aimed at measuring and managing the injury severity of Head injury patients. Severe head injury management in the intensive care unit is extremely challenging due to the complex domain, the uncertain intervention efficacies and the time-critical setting. Expert system was adopted to automate the management process. This Paper examines the feasibility and effectiveness of an expert system-an innovative tool in managing the head injury patients. Those factors, which were found to be statistically significant by the application of various sophisticated multivariate statistical models such as Log-linear, Logistic regression, Survival analysis using SPSS package 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 cumulative effect of the immediate and indirect effects of head injury is usually devastating, not just for the victim, but also for his or her family. Accident at the productive age is a total loss to the family, society and nation at large and it leads to the loss of active life and manpower. Fast and aggressive treatment is therefore essential for increasing the chances of a good outcome.

Key words: Severe head injury, Glasgow Comma Scale (GCS), *Intra Cranial Pressure (ICP), Expert* system, Artificial Intelligence, Prognostic guideline, Priority care and treatment.

I. INTRODUCTION

Constant increases in high velocity accidents and violence over the past decades have made the management of severe head injury of prime importance in to-day's neurosurgical practice. 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 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. It would be a substitute to the paper-based guidelines used by the hospital support staffs.

II. MATERIAL AND METHODS

The study was carried out prospectively in the Department of Neurosurgery, Institute of Neurology, Government General Hospital (GGH), Chennai, South India. The institute, popularly known as Madras Institute of Neurology, is a large tertiary cares unit. It serves as a referral hospital for individuals who have met with an accident and to the head injury patient. It caters to Chennai city population (about 60 lakhs) and also, to the people living near the border in the neighboring states. A structured proforma was designed to incorporate all the clinical variables which were found to be risk factors for head injury, post injury complications and risk for death after head injury. The following required information was collected from patients suffering from Head injury. Clinical parameters like Loss of Consciousness (LOC) $<$ 1 hour, (LOC) $>$ 1 hour, 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), Headache and Scalp injuries were compared with GCS scores on admission (GCS 1), after an interval of 2 days (GCS 2) and one week (GCS 3) and corresponding serial ICP values. 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 Scale is considered as Group I: Severe Head injury (3 – 8) Group II: Moderate Head injury (9 – 12) Group III: Mild Head injury (13 – 15). The Glasgow Outcome Scale was recorded in 801 cases. Those individuals whose Glasgow Coma score was less than or equal to eight were considered as Severe Head Injury (SHI) patients and they were considered for the study. The Glasgow Outcome Scale was recorded in 801 cases. Those individuals whose Glasgow Coma score was less than or equal to eight were considered as Severe Head Injury (SHI) patients and they were considered for the study.

Expert System: Expert systems first emerged from the research laboratories of a few leading U.S. universities during the 1960s and 1970s. They were developed as specialized problem solvers which emphasized the use of knowledge rather than algorithms and general search methods. This approach marked a significant departure from conventional Artificial Intelligence (AI) systems architectures at the time.

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. For example, there are expert systems that can diagnose human illness, and MYCIN is one of the popular expert systems in medical field and was built in mid 1970s. This provides consultative advice on diagnosis and the treatment for infectious blood diseases. MYCIN facilitates high level performance of selecting antibiotic therapy for Bacteremia (infectious blood disease). Apart from this there are expert systems on various aspects such as financial forecasting, schedule routes for delivery vehicles, analysis of structures of chemical compounds and planning of actions sequentially etc. Some expert systems are designed to take the place of human experts while others are designed to aid them.

At the dawn of the birth of new software, commonly called second generation expert systems, we can catch a glimpse of what are “first generation” expert systems, at least to extract certain characteristics which will serve to define expert systems. The characterization of the type of software can be achieved in two ways: through its functional analysis and it structural analysis. The functional analysis consists in defining the potential use of software by knowledge of the problems it can solve, the questions it can answer. From this analysis a user can understand the possible functions of the system. These functions are classified, arranged in classes and divided into subclasses. This classification establishes the relevance of the functional analysis. The structural analysis defines the architecture of the software, ie., its decomposition into distinct modules and the way in which the diverse modules are related to each other.

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. Wherever human expertise is needed to solve problems, expert systems are likely candidates for application. Application domains include law, chemistry, biology, engineering, manufacturing, aerospace, military operations, finance, banking, meteorology, geology, geophysics and more.

An expert system is a set of programs that manipulate encoded knowledge to solve problems in a specialized domain that normally requires human expertise. An expert system’s knowledge is obtained from expert sources and coded in a form suitable for the system to use in its inference or reasoning processes. The expert knowledge must be obtained from specialists or other sources of expertise, such as texts, journal articles and data bases. This type of knowledge usually requires much training and experience in some specialized field such as medicine, geology, system configuration, or engineering design. Once a sufficient body of expert knowledge has been acquired, it must be encoded in some form, loaded into a knowledge base, then tested, and refined continually throughout the life of the system.

Different Categories of Expert System: Expert systems can be classified into different categories as stated below:

1. Interpretation Systems: This includes analysis of intelligence by way of surveillance; understanding of speech, image analysis etc. Meanings are expressed symbolically and situations described as a result of observation.
2. Prediction Systems: These systems infer liable consequences of given situations, such as economic and weather forecasting, demographic prediction, crop estimation and military etc.
3. Diagnostic Systems: These systems analyze the organizations' performance and diagnose the failure even in the medical field.
4. Design Systems: These systems develop circuit layout and building design etc.
5. Planning Systems: These systems help in automatic planning in project management, routing, communication, military operation etc.
6. Instruction Systems: These systems are otherwise called "Education and Training systems" which incorporate diagnosing and debugging of sub-system. These systems diagnose the weakness in the students' knowledge and identify appropriate remedies and also plan a tutorial interaction to deliver remedial knowledge to the student.
7. Model-Based Systems: Here the knowledge is based on human expertise and is represented as rules with which a model is designed as to understand the system and then used to identify the course of the equipments failure.

Architecture of Expert System:

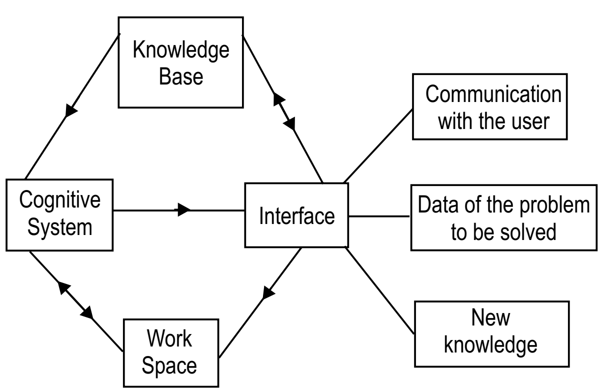

Fig. 1. Architecture of Expert System

Tools to design Expert Systems: Expert Systems can be developed by writing programs using certain programming languages, such as, Fortran, Pascal, C++, Visual Basic and dbase. The languages like Prolog (Programming in Logic) and Lisp (List in Programming) are most significant and are used for designing Artificial Intelligence systems. There are expert systems shells, which are readymade software packages, which facilitate designing of expert system without writing complicated programs. They provide the inference engine and user interface commands. It has the facility to construct the rules in spoken English language and has a built in editor.

Expert System as an effective tool for knowledge organization: Expert system facilitates organization of knowledge in such a manner, that it fills up the gap of the absence of an expert in any field. An expert system with hypertext facility is particularly useful in organizing knowledge in logical manner and facilitates storing of large amount of information with a very effective retrieval mechanism. Hence these two techniques namely expert system and hypertext have been chosen by the researcher to design the expert system of head injury patients.

An Expert System consists of four modules as shown in Fig. 1. The knowledge base 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 (Peterson BAN W, 2002).

Knowledge base contains facts and an inference procedure to utilize the knowledge, which is called as inference engine. A "user interface" program has also been incorporated in the expert system, which enables a user to interact with the system. Expert System is a versatile tool, which can be used as multi-purpose systems such as decision support system, diagnostic system, self-learning tool, and teaching aid etc.

User Interface: The hyperlinks provided in the knowledge base facilitate non-sequential browsing. A program is written using MS Access and Visual Basic which facilitates to retrieve relevant information for a specific structured query. Further, the expert system provides a "Tutorial Interaction" for the target users which enable "knowledge testing" in managing the head injury patients.

System Interaction: Apart from the user interface with the system, the system itself puts forth some questions along with some options. The users should select the option and from the interaction, the system will draw conclusions and try to diagnose the disease and provide information on treatment for the particular disease.

The methodology adopted to design an expert system is illustrated in Fig. 2.

Characteristic Features of Expert Systems: Expert systems use knowledge rather than data to control the solution process. "In the knowledge lays the power" is a theme repeatedly followed. Much of the knowledge used is heuristic in nature rather than algorithmic

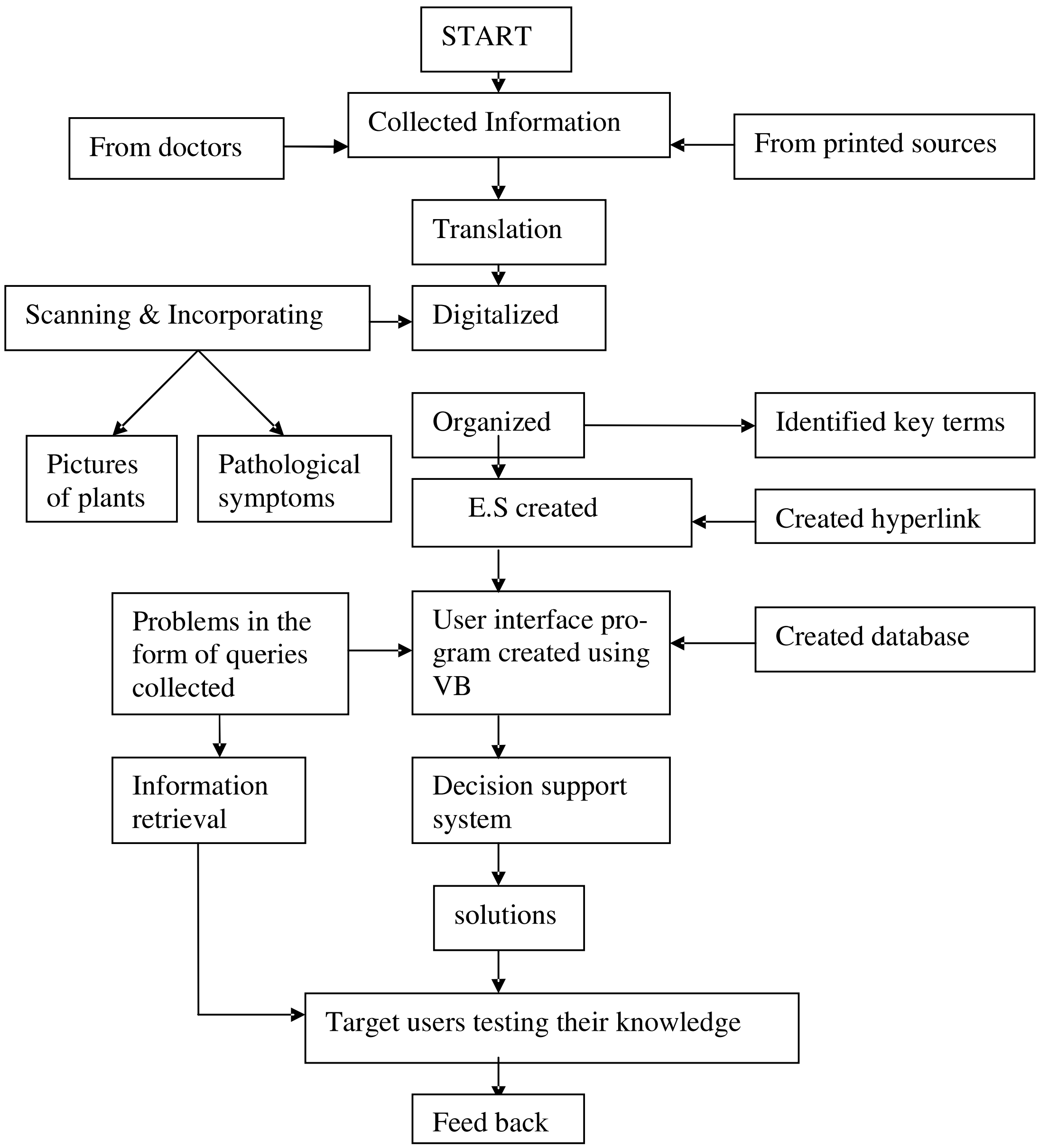

Fig. 2. Methodology of Expert System

- The knowledge is encoded and maintained as an entity separate from the control program. As such, it is not compiled together with the control program itself. This permits the incremental addition and modification of the knowledge base without recompilation of the control programs. Furthermore, it is possible in some cases to use different knowledge bases with the same control programs to produce different types of expert systems. Such systems are known as expert system shells since they may be loaded with different knowledge bases.
- Expert systems are capable of explaining how a particular conclusion was reached, and why requested information is needed during a consultation. This is important as it gives the user a chance to assess and understand the system's reasoning ability, thereby improving the user's confidence in the system.
- Expert systems use symbolic representations for knowledge (rules, networks, or frames) and perform their inference through symbolic computations that closely resemble manipulations of natural language.
- Expert systems often reason with Meta knowledge: that is, they reason with knowledge about themselves, and their own knowledge limits and capabilities.

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 (Elaian Rich and Kevin Knight, 2001). They include areas such as:

- Different types of medical diagnoses (internal medicine, pulmonary diseases, infectious diseases, and so on).
- Diagnosis of complex electronic and electromechanical systems.
- Diagnosis of diesel electric locomotion systems.
- Diagnosis of software development projects.
- Planning experiments in biology, chemistry, and molecular genetics.
- Forecasting crop damage.
- Identification of chemical compound structures and chemical compounds.
- Location of faults in computer and communications systems.
- Scheduling of customer orders, job shop production operations, computer resources for operating systems, and various manufacturing tasks.
- Evaluation of loan applicants for lending institutions.
- Assessment of geological structures from dip meter logs.
- Analysis of structural systems for design or as a result of earthquake damage.
- The optimal configuration of components to meet given specifications for a complex system.
- Estate planning for minimal taxation and other specified goals.
- Stock and bond portfolio selection and management.
- The design of very large scale integration (VLSI) systems.
- Numerous military applications ranging from battlefield assessment to ocean surveillance.
- Numerous applications related to space planning and exploration.
- Numerous areas of law including civil case evaluation, product liability, assault and battery, and general assistance in locating different law precedents.
- Planning curricula for students.
- Teaching students specialized tasks (like trouble shooting equipment faults).

Past efforts to develop guidelines for the management of patients with severe head injury relied on authors' expert opinion and practice experience and, therefore, had an element of subjectivity. Recently, with the advent of a methodology to develop guideline documents based on scientific method, there has been a dramatic increase in clinical practice guidelines with subsequent reports showing improvement in patient care and a reduction in medical time and cost.

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 Scale 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. 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 clinical practice parameters, scientific evidence is insufficient for standards of care, as is generally the case in most of current medical practice. Upgrading clinical practice parameters from option to guideline to standard will require focused, well-designed and carefully implemented clinical research trials. Harmanec *et al.*, 2001 adopted Decision analytic approach to severe head injury management 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.

Charles Sheeba Dora *et al.*, 2001 designed a head injury decision support system (HIDSS). They have 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. Gnana Sekari, G *et al.*, 2001 designed an Expert system for Siddha system of Medicine.

Expert system for the Early Management of Patients with Severe Head injury: The patients, who are suffering from severe head injuries, usually enter a state of coma. To treat such patients, who are prone to a high risk of mortality, the neurologist adopts certain aggressive and informed decision-making procedures. Also suggest the treatments based on the values of certain monitored parameters.

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:

(i) To assess the effectiveness of the various treatments available for a particular patient with severe head injuries.

(ii) 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:

(i) The protocol used at the Neuroscience Intensive Care Unit.

(ii) 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.

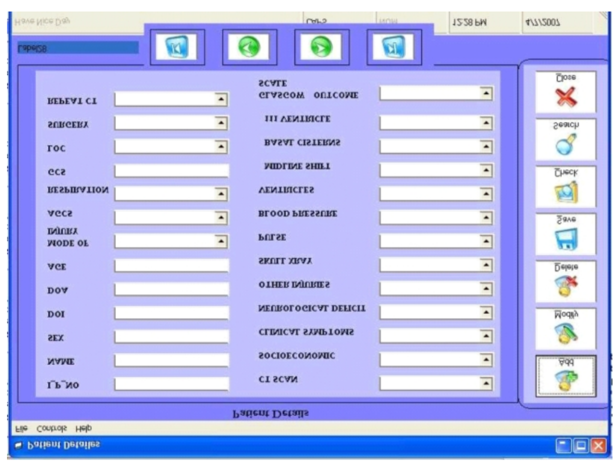

Fig. 3. Entry form of the expert system

The system interaction program has been using Visual basic. The window offers the options "Add", "Modify", "Delete", "Save" and "Search." These option buttons facilitates the user to add, modify, delete, save and search the record as and when required. The "Check" button enables the user to view the patients for priority care. The other button "Close" facilitates the user to come out of the system interaction program, if he/she desires.

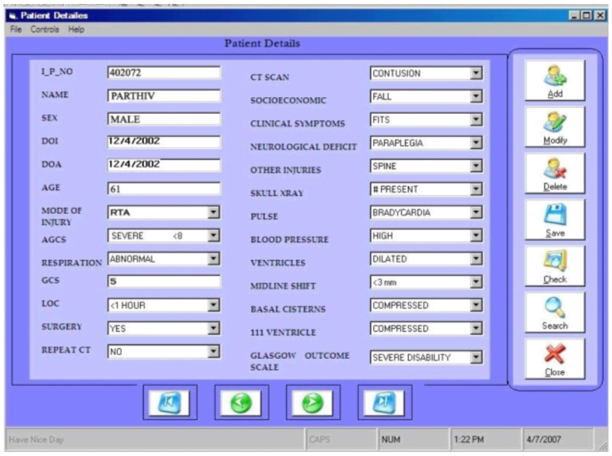

Fig. 4. Screen – Shot highlights the patient details.

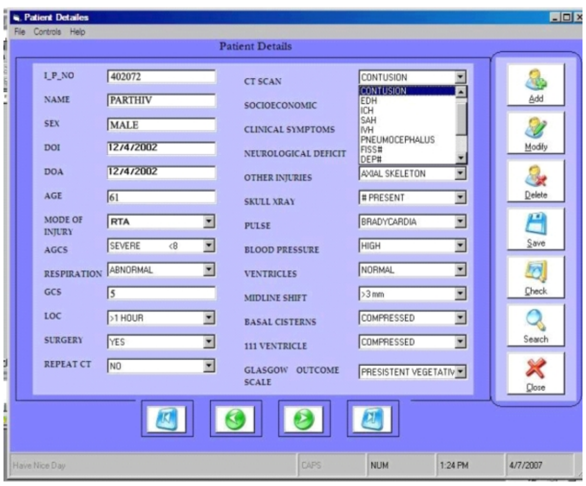

Fig. 5. Screen – Shot highlights the options in Respiration

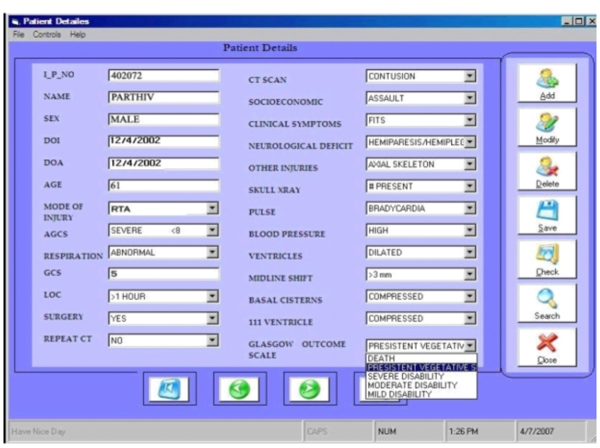

Fig. 6. Screen - Shot highlights the options in CT Scan

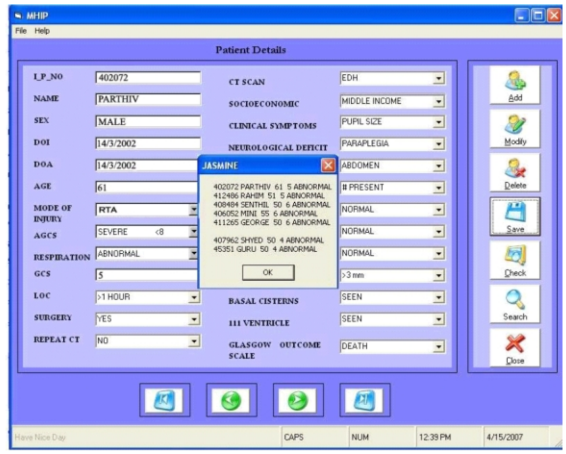

Fig. 7. Screen – Shot highlights the Glasgow outcome scale (GOS)

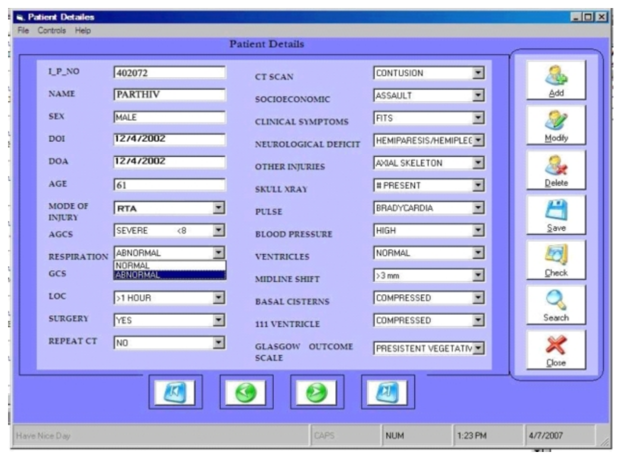

Fig. 8. Screen – Shot of an Expert system MHIP shows the patients details and lists out the Patients for Priority care.

IV. RESULTS

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).

Table 1. Study subjects

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

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).

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

The poor outcome was formed by combining patients' outcome with Death and Persistent Vegetative State. The Good outcome was formed by combining patients' outcome with Good Recovery, Mild Disability and Severe Disability. It was alarming to observe that around 60% of the severe head injury cases were dead while only 18% of the mild head injury cases were dead and 67% had good recovery among the mild head injury cases. After severe injuries, the question was whether or not the patient would survive? And if he did, what was the likelihood of persistent disability? Therefore it became useful to identify patients who had a reasonable probability of survival. Our study attempt to determine an optimum set of indicators for prognostication to minimize medical complications associated with severe head injuries and to give priority in treating the severe head injury patients than the mild head injury patients. Further results were restricted only to the severe head injury patients.

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. Others were because of occupational, domestic activities, etc. 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).

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	98.09	100	50	100	4.5	25	100	25	20	100
15-25		71.43	66.67	1.91		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

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.

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

Age Group	Mode										
	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	1.66	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	

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 ie., 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 study has derived a set of variables and reduced the list of potential predictors to a minimal one, which is not likely to be affected by expensive, sophisticated diagnostic and curative equipment. 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.

V. DISCUSSION

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, the loss of friends, the loss of intimacy and the loss of freedom. The most common causes of severe head injuries are motor vehicle accidents, especially motorcycle accidents and accidents at constructions sites. The traumatic head injury usually has debilitating consequences ranging from a mild disability to a vegetative survival and death. The consequences are often caused by a secondary brain injury resulting from lesions, raised intracranial pressure, ect. 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 most important aspect in treating patients is to make them psychologically stable. Periodic review of the patient's condition and improvement in various physical and psychological factors would help the physicians to change the therapy for a speedy recovery. Modern management of head injuries at the neurosurgical unit involves continued ventilation, surgery, intensive care unit management of intra-cranial pressure and cerebral perfusion pressure, oxygenation, etc.

An accident which involves injury to the head and results in loss of consciousness, even for a very brief period, is one of the clearest indications that the brain may have been affected by a blow to the head. A confusional state involving uncertainty about time, date, and location and/ or a period of memory loss for the events surrounding the head injury are also indications of trauma to the brain. These symptoms should be taken seriously and the person affected should receive immediate medical attention. The person's state of consciousness, orientation to time, place and immediate memory function (e.g., remembering a series of four numbers) should be evaluated periodically. An expert system MHIP would definitely help the clinician in identifying the patient who needs the immediate medical attention.

Expert System MHIP is an innovative tool for managing the head injured patients. Given a patient state, the purpose of the MHIP is to list out the patients according their severity for priority care. Statistical techniques had identified that the most consistent risk factors for mortality are older age, low Glasgow coma scale and abnormal respiratory rate among patients with severe head injury and are found to be statistically significant. Hence those patients, who are older, having low Glasgow coma scale 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.

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