Article NIMHANS Journal

# Classification of Prognostic Factors in Head Injury: Structural Equations Model

**Volume: 15 Issue: 02 April 1997 Page: 143-155**

V G Kaliaperumal ,

Reprints request

, A R Khalilian,

- *Department of Biostatistics*

G N Narayana Reddy &, B S Das, - *Department of Neurosurgery, National Institute of Mental Health & Neuro Sciences, Bangalore 560 029, India*

## *Abstract*

This study reports classification of prognostic factors related to out-come after head injury as classified by the structural equation model. One hundred and eighty five patients constituted the study, out of which 51 patients died in the hospital, 11 were vegetative at discharge, 91 were discharged with deficit and 32 made good recovery. The outcome was assessed clinically and socially. Twenty predictors were employed. The structural equation model with two outcome variables and 19 predictors identified four latent variables. Pre-traumatic factor, traumatic factor, post-traumatic factor, and complications during hospitalization influenced the outcome from head injury. To obtain good recovery, all these factors have be taken into account to adopt a suitable strategy to manage patients with head injury.

Key words -

**Head injury,**
**Outcome,**
**Structural equations models**
**Head injury,**
**outcome,**
**structural equations models**

Researchers have attempted to classify the prognostic and risk factors in head injury outcome ideologically. Nau and his associates [1] have differentiated three types of factors: pre-traumatic, traumatic, and post-traumatic. Rose et al [2] differentiated avoidable and non avoidable factors contributing to death after head injury. Lokkeberg et al [3] classified treatment and non-treatment variables. The purpose of the present report is to derive empirically typology of prognostic factors with the application of structural equations models [4], [5].

## Material and Methods

## Patients

This series consisted of 185 patients with head injury who were admitted into our center from January 1983 through February 1985. Data was collected prospectively using a standard pre-coded proforma so that the data could be computerised. Patients dying within 24 hours were excluded. The age of the patients ranged from 3 to 70 years with mean 30.1 (± 16.2) years. Majority (86.5%) of patients were males.

Traffic accident was the predominant cause of injury accounting for 73.5%, followed by fall from a height accounting for 21.1%. Only 4 (2.2%) patients were admitted within one hour after injury, 13.5% within 2 hours, and 62.7% within 6 hours. Evidence of consumption of alcohol was reported in 16.2%.

The clinical state on admission was graded according to the Glasgow Coma Scale (GCS) as defined by Jennett et al [6] and Teasdale et al [7]. Seventy-four (40%) patients had severe head injury (GCS 3-7). The patients were treated in the neurosurgery ward. The changes in the clinical states of the patients during their stay in the hospital were regularly monitored.

## Clinical outcome

The clinical outcome at the time of discharge was assessed according to the Glasgow Outcome Scale (GOS) [8]. The clinical outcome was graded as good recovery, discharged with deficiency, vegetative state, and dead.

## Social outcome

The social outcome was measured on a four-point scale, viz., excellent, good, fair, and dead.

## Predictor variables

Twenty predictor variables were considered for the present study. Out of these, some were present before the patient met with the accident, some before admission or before patients commenced treatment and still some were present after admission but before the measurement of final outcome. The presence of temporal relationship among these variables leads itself to the construction of a model in which variables occurring earlier in time could predict the value of those occurring later. The utility of such a model can be evaluated by structural equations models and path diagram [9], [10]. Since temporal sequence is important in casual models, care has to be taken in selecting predictors.

Three variables appearing in GCS were among 20 predictors. The coding for the predictors and response (outcome) variables are given in Table 1. The severity of neurological deficiency has been measured by several other variables, apart from GCS scale. Abnormal deep tendon reflexes, abnormal respiration, presence of decerebrate spasm, impaired corneal reflex, abnormal occulocephalic reflex, abnormal plantar response, muscle tone, complications such as cerebral oedema and post-traumatic seizures, and heart rate were some of the predictors studied. Age of the patient, evidence of consumption of alcohol at the time of accident, and the time interval between accident, and admission were also included as predictors. (Table next page)

***Table I - List of predictors and outcome variables***

**Predictor Variables**

V1 Age in years

V2 Between Admission & Accident

1. Admitted within 6 hours

0 Admitted after 6 hours

√ 3 Consumption of Alcohol
1. Present
0 Absent

√ 4 Best Motor Response
6. Obeys
5. Localisation
4. Withdraws
3. Abnormal Flexion
2. Extensor
1. Nil

√ 5 Eye Opening Response
4. Spontaneous
3. To Speech
2. To Pain
1. None

√ 6 Verbal Response
5. Oriented
4. Confused Conversation
3. Inappropriate Words
2. Incomprehensible Sounds
1. Nil

√ 7 Deep Tendon Reflex
1. Abnormal
0. Normal

√ 8 Respiration
1. Abnormal
0. Normal

√ 9 Decerebrate Spasm
1. Present
0. Absent

√ 10 Corneal Reflex
1. Impaired
0. Normal

√ 11 Occulocephalic Response
1. Abnormal
0. Normal

√ 12 Plantar Response
1. Abnormal
0. Normal

√ 13 Muscle Tone
1. Impaired
0. Normal

✓ 14 Cerebral Oedema
1. Present
0. Absent

✓ 15 Post-traumatic Epilepsy
1. Present
0. Absent

✓ 16 Complications - global
1. Present
0. Absent

✓ 17 Breathing at Admission
1. Abnormal
0. Normal

✓ 18 Systolic BP
1. Above 150
0. Below 150

✓ 19 Diastolic BP
1. Above 100
0. Below 100

✓ 20 Pulse Rate
1. Below 70, above 120
0. Between 70-120

***Outcome Variables***

✓ 21 Clinical Outcome
1. Recovered
2. With deficiency
3. Vegetative state
4. Dead

✓ 22 Level of Functioning
1. Excellent
2. Good
3. Fair
4. Dead

The gender of the patient, cause of injury and mode of transport were not studied in the proposed model. Intracranial pressure record was not performed for many patients and hence deleted from the predictors. Similarly, biochemical parameters and neuro psychological variables were not included in the analysis.

## Structural Equations Model

S.Wright, a geneticist, has developed the method of path coefficient analysis and has continuously employed it in agricultural research [11], [12], [13], [14], [15], [16]. Briefly speaking, in path coefficient analysis, between the response variable (effect) and a given predictor variable (cause) is decomposed into a linear combination of direct effect of the predictor under consideration and its indirect effects through other predictors with which the former was correlated.

Psychologists have worked with latent variable models over several years. However a real breakthrough was achieved by Joreskog [17] who found proper statistical estimation and inference procedures. Impressive body of literature was also available in econometric structural equation models [18], [19], [20], [21]. As a direct result of Joreskog's breakthrough, the latent structural equations modeling brought together psychometric, econometric, and path analysis together so that the best features of all three methods can be exploited simultaneously.

A latent variable is a hypothetical construct invented by a scientist for the purpose of understanding a research area. The constructs, which are not measured directly, are related to each other as specified by the researcher's theory. When the relations between latent variables and the relation between latent variables and measured variables are specified in mathematical form by simultaneous system of highly restricted linear regression equations, one obtains a model having certain structural form and certain unknown parameters. The model purports to explain the statistical properties of the measured variables in terms of the latent variables.

The primary statistical problem in structural equation model is obtaining estimates of the parameters of the model, and determining the goodness-of-fit of the model to the data. If the model could not be rejected statistically, then the model is a possible representation of the causal structure [22], [23].

## Path diagram

Path diagrams are useful to display graphically the pattern of causal relationships among sets of measured and latent variables. A brief note on path diagrams is given by Kaliaperumal et al [22].

## EQS program

The analysis reported in this communication was carried out with EQS program [5]. The EQS implements a general mathematical and statistical approach to the analysis of linear structural equation systems. The advantage of this approach, when used in an appropriate hypothesis testing mode, is the structural parameters presumably represent relatively invariant parameters of a causal process and are considered to have more theoretical meaning than ordinary predictive regression equations, especially when the regression equation is embedded in a series of simultaneous equations designed to implement a substantive theory [24].

Maximum likelihood (ML) estimation, least square (LS) estimation, or generalized least square (GLS) estimation of the parameters could be obtained with EQS. The chi-square is used to determine the probability of obtaining a chi-square value as large as or larger than the value actually obtained given that the model is correct. When the null hypothesis is true, the chi-square probability should exceed the standard ($P < 0.05$) cut-off in the chi-square distribution. Bentler-Bonnet (1980) Fit Index is based on the fit function as well as an appropriate null model. Value of this index that exceeds 0.9 indicates a good-fitting. In the case of large sample, it is possible to get fit index exceeding 0.9, but p-value less than 0.05. In such cases, the overall fit index may be more appropriate index [25].

Statistical significance tests are performed on the unstandardized parameter estimates. The test statistic is the parameter estimate divided by the standard error and is a normal Z - test. value of [Z] which exceeds the standard normal critical value of 1.96 associated with a 0.05 probability level indicates that the parameter is significantly different from zero.

EQS and in general, structural equations models could be most effectively used to test for the alternative and competing models. In the case where competing models are tested and where there is a difference in the models of a single path being eliminated in the more restricted model, the significance of the path in the unrestricted model is equivalent to the chi-square difference test of the two competing models [5].

EQS calculates Mardia's [26] multivariate kurtosis and also lists possible outliers when original data was the input. Linear dependency among the variables, if any, is listed out. For simulation studies, EQS is much suitable in which Wald test identifies the parameters which could be dropped and Lagrange Multiplier test identifies the parameters which could be added.

---

## Results

Table II presents simple correlation coefficients between outcome measures on one hand and 20 predictors on the other. These coefficients would throw some light on the prognostic importance of the predictors. In the case of clinical outcome, highest correlation (r = 0.546) was observed for the best motor response, followed by eye opening response (r = 0.451) and verbal response (r = 0.421). Among the complications, cerebral oedema was highly related to poor outcome. Abnormal respiration at admission, blood pressure, and pulse rate were all significantly related to outcome. Presence of post-traumatic epilepsy, time interval between admission and accident, the evidence of consumption of alcohol at the time of accident, and the pulse rate were not related to outcome.

***Table II - Correlation of outcome measures with 20 predictor variables***

***Table II - Correlation of outcome measures with 20 predictor variables***

Note : Sig r values for 183 d.f 5% lrl ( 0.143
1% lrl ( 0.187
0.1% lrl ( 0.236°

### Logistic regression

The clinical outcome variable was transformed into a binary type by assigning unity for good recovery or discharged with deficiency, and zero otherwise. The results of logistic regression [27], employing one predictor at a time, are presented in Table III. Four predictors did not have significant relation with outcome, the inference of which was comparable with that of the simple correlation analysis.

***Table III - Logistic regression analysis of clinical outcome as binary and taking one predictor at a time***

***Table III - Logistic regression analysis of clinical outcome as binary and taking one predictor at a time***

Under the assumption that predictors were antecedent factors, the results of logistic regression are more amenable and convenient for interpretation, and particularly for the binary type of predictors. If the odds of survival was one for abnormal respiration, then it was 12.195 for the normal respiration. This odds could be as low as 3.906 or as high as 38.462. Thus, even at the worst case, normal respiration could lead to good result four times (3.9) as compared to abnormal respiration.

### Structural equation model

The structural equation model fitted to the data is presented in the path diagram. The model consisted of 21 measurement variables out of which two were dependent (outcome) variables. Global complications measure was not employed in the model due to certain identification problem. The model included six latent variables, one for outcome measures and five for the predictors. Thirty-five regression weights (free parameters) and 20 error variances were estimated. The Bentler-Bonett fit index [28] was 0.999 and the chi-square test of goodness of fit was not significant ($X^2$ = 183.880; d.f = 176; P = 0.327) indicating that the proposed model well fitted the data. All regression weights were significant in the model. The path diagram (Figure 1) indicates the causal paths together with the direct effects (standardized regression weights) and direction (sign).

***Path diagram for classification of prognostic factors in head injury***

F6 is the latent variable affecting both the clinical outcome and social outcome. The loadings on these predictors were almost equal. The outcome factor F6 was affected directly by four latent predictor variables, F1 - F4, while F5 did not affect out-come.

Age of the patient, abnormal blood pressure, and normal pulse rate constituted the latent variable F1. F2 affected directly 12 out of 19 predictors. Low GCS scores (severe head injury), decerebrate spasm, corneal reflex, occulophalic response and muscle tone were some of the predictors affected by F2. Latent variable F3 represented the time interval between accident and admission and GCS. F4 was related to complications (cerebral oedema), abnormal breathing at admission, and age.

Factor F5 has significant loadings on three predictors, viz. : post-traumatic epilepsy, time interval between accident and admission, and age of the patient. F5 did not affect outcome directly or indirectly.

The age of the patient had two paths to outcome, one through F1 (V1 → F1 → F6) and the other through F4 (V1 → F4 → F6). Higher the age of a patient poorer was the outcome. Moreover, higher age had also increased the likelihood of getting post-traumatic seizures.

Less time interval between accident and admission correlated highly with the best motor response, eye opening response, and verbal response, and thereby increased the chance of good recovery. The presence of post-traumatic epilepsy and the evidence of alcohol consumption at the time of accident facilitated for early admission.

Among the vital signs, blood pressure played a good role in predicting the out-come. While systolic blood pressure had only one path with indirect effect -0.126 (=-0.153 × 0.825), diastolic blood pressure had two paths with indirect effect -0.232 (=-0.153 × 0.695 - 0.188 × 0.667). Thus, the diastolic BP was more sensitive in predicting outcome than the systolic BP.

Abnormal pulse rate was an indicator of poor outcome, with the direct effect being negative (-0.179) and its indirect effect via F1 was positive (-0.186) (-0.153 = 0.028) but negligible. Evidence of consumption of alcohol reduced the chance of abnormal pulse rate. In fact, the early admission via alcohol consumption reduced the chance of abnormal pulse rate. (V2 → V3 → V21).

Abnormal breathing at admission was an indicator of poor outcome. However, if the patient was younger, the abnormal breathing had diminished effect on poor outcome (V18 → F4 → F6).

Motor response, eye opening response, and verbal response affected outcome through two paths (V4 → F2 → F6 and V4 → F3 → F6). Motor response had high loading on F2, verbal response more loading on F3, and eye opening response had almost equal loadings on both F2 and F3.

Complication (cerebral oedema) affected the outcome through two paths, one via F2 and the other via F4. Its effect was negative on both paths. In one path, complication affected outcome along with the other neurological deficits and in another along with the higher age and abnormal breathing at admission.

Factor F1 had higher loading on blood pressure, followed by the age of the patient. This factor could be termed as pre-traumatic factor. Best motor response had highest loading on F2 and hence F2 is essentially the traumatic factor. Apart from GCS, F3 is related to time interval between accident and admission and hence could be called the post-traumatic factor. Finally, F4 is the post-operative factor. F5 is the post-traumatic seizures factor.

## Discussion

In head injury, relationship between early features and the outcome has to be established to evaluate alternative therapeutic methods [1], to counsel the family members and to allocate the costly hospital facilities [29]. For this purpose attention has to be made to classify both the outcome and the characteristics of the initial damage and early complications. The Glasgow Outcome Scale [30] allows the overall social outcome of most patients to be assessed reliably on the basis of a structured interview which concentrates on social and personal functioning without the need for detailed neurological and psychological evaluation. The Glasgow Coma Scale [6], Edinburgh-2 Coma Scale - E2 CS (M) [31], Reaction Level Scale - RLS85 [32], and Glasco-Liege Scale [33] on the other hand fulfill the need for describing the initial damage.

This report concentrates on the classification of initial damages and the subsequent complications and evaluates the effect of such classified factors on the outcome which was measured by Glasgow Outcome Scale. Bruce et al [34], Teasdale et al [35] and Nestvold et al [36], among others stressed the need to include certain features like pupillary and occilocephalic responses, respiration and vital signs to categorize clearly the neurological status of the patient since the coma scale does not adequately define the severity of the injury. Born et al [33] have shown that the predictive capabilities of brain stem reflexes were greater than those of motor responses for severely head injured patients. Bruce et al [34] also noted that the secondary head injury measured by brain swelling, intracranial hypertension, cerebral ischemia complicated by infection, or pulmonary difficulties contribute significantly to poor outcome. Apart from the severity of primary and secondary head injuries, certain inherent characteristics of the patient such as age and other illness also influence the outcome [37]. Carlsson et al [38] noted that the age-related increase in mortality in their series of 496 patients was due to systemic medical complications. Overgaard and Christensen [39] demonstrated by analysing 201 patients injured in road traffic accidents that age and post-traumatic hypertensions were both related to poor recovery.

While the literature throws some light on the classification of initial damages following clinical observation, no analytical study was reported in classification of neurological severity or outcome after head injury. This study has identified four uncorrelated factors associated with the outcome. Among these, the most important one is the neurological severity of head injury (F2). Nau et al [1] called this as "traumatic-factor". Predominantly this factor is described by the Glasgow scale score and other neurological deficits. This factor also includes "deep tendon reflexes". This has an agreement with Nestvold et al [36] who noted that head injuries are often combined with other body injuries, especially to the limbs, and they emphasized the importance of access to speciality in different fields in treating head injured patients.

Nau et al [1] suggested that the biological factors such as age-sex and pre-existing diseases could form one factor, known as pre-traumatic factor. This study identifies one such factor (F1) which is characterized by the age of the patient, hypertension and pulse rate. The significance of the age and blood pressure in predicting outcome was well documented [38].

How the patient is managed immediately after the head injury matters in predicting the outcome. Among other things, the time between the accident and the arrival at the emergency room [29], [37], [40] time to start of intubation, and the mode of transport utilized to transfer the patient from the scene of the accident to the emergency room have to contribute some unknown effect to outcome [3]. The recognition of these predictors has led to the development of advanced systems of emergency and primary care that are expected to reduce medical complications associated with the severe head injury. However, newer emergency and primary care system is often influenced by the local societal pressure, public policy, the capacity of the local emergency network to respond to trauma [3]. The factor, F3, resulted in this study, is specifically the factor under discussion. This factor has to affect motor, eye-opening, and verbal responses as well.

The traumatic factor (F2) facilitates early prediction of outcome which inevitably includes some which are unduly optimistic because some complications such as meningitis or pulmonary embolism may occur in patients whose outlook previously appeared hopeful. Narayan et al. [41] found that in every case where an overoptimistic error had been made in predicting outcome, a non-neurological complication was responsible for the unexpected outcome. The post-operative complications such as cerebral oedema or infection may also affect outcome. Factor F4 specifically measures this aspect of parameters which also predict outcome from head injury. Warme et al. [42] report an establishment of a neurological intensive care unit to prevent or to minimize secondary brain damage which resulted 15% increase in the rate of good recoveries.

The importance of alcohol was under lined as a contributing factor in head injuries [36]. Drunkenness of the patient makes clinical evaluation more difficult. We found that the presence of evidence of consumption of alcohol at the time of accident did not influence the outcome directly. On the other hand, alcohol consumption and early admission correlated positively. Patients with alcohol consumption displayed less likelihood of abnormal pulse rate.

Post-traumatic epilepsy constituted one factor together with the time between accident and admission and age. This factor had no effect on the clinical and social outcome. In simple correlation analysis also post-traumatic epilepsy did not correlate with the clinical outcome.

The classification of initial conditions and subsequent complications after head injury indicated the severity of the head injury. The biological factor (age-sex and pre-existing diseases), traumatic factor, how the patient was managed immediately after the head injury, and the complications developed in the head injury ward, before or after operation are to be considered and the patient has to be managed accordingly to get the best possible outcome.


1.Nau H E, Reinhard V, Bongartz E B, Flordorf R, Risk factors in serve head injury
*Acta Neurochirugica Suppl* Page: 28: 174-8, 1979
2.Rose J, Valtomen S, Jennett B, Avoidable factors contributing to death after head injury
*British Medical Journal* Page: 2: 615-8, 1977
3.Lokkerberg A R, Grimes R M, Assessing the influence of non-treatment variables in a study of outcome from severe head injuries
*Journal of Neurosurgery* Page: 61; 254-62, 1984

4.Joreskog K G, Sorbom D, *LISREL 7 A guide to the program and applications. Chicago : SPSS*1988
5.Bentler P M, Wu E J C, *EQS/PC and EQS/EM. User's Guide. BMDP Statistical software, Los Angeles*1989
6.Jennett B, Tesadale G, Galbraith S, Pickard J, Grant H, Braakman R, Avezaat C, Mass A, Minerhoud J, Vecht C J, Heiden J, Small R, Caton W, Karze T, Severe head injuries in three countries
*Journal of Neurology, Neurosurgery & Psychiatry* Page: 40: 291-8, 1977
7.Tesadale G, Jennett B, Assessment of coma and impaired consciousness. A practical scale
*Lancet* Page: ii: 81-3, 1974
8.Jennett B, Teasdale G, Braakman R, Minderhoud J, Knill-Jones R, Predicting outcome in individual patients after severe head injury
*The Lancet* Page: I: 1031-4, 1976
9.Foa E B, Grayson J B, Steketee G S, Doppelt H G, Turner R M, Latimer P R, Success and failure in the behavioural treatment of obsessive-compulsives
*Journal of Consulting & Clinical Psychology* Page: 51: 287-97, 1983
10.Blalock H M, *Causal Inferences in Nonexperimental research Chapel Hill: University of North Carolina Press*1964
11.Wright S, Correlation and causation
*Journal of Agricultural Research* Page: 20: 557-85, 1921
12.Wright S, *Corn and hog correlations. U.S. Department of Agriculture Bulletin 1300. Washington : Government Printing Office*1925
13.Wright S, Statistical methods in biology
*Journal of the American Statistical Association Suppl. Papers and Proceedings of the 92nd annual me*
Page: 26: 155-63, 1931
14.Wright S, The method of path coefficients
*Annals of Mathematical Statistics* Page: 5: 161-215, 1934
15.Wright S, The genetical structural of populations
*Acta Endocrinologica* Page: 15; 323-54, 1951
16.Wright S, Path coefficients and path regressions : Alternative or complimentary concepts
*Biometrics* Page: 16: 189-202, 1960
17.Joreskog K G, A general approach to confirmatory factor analysis
*Psychometrika* Page: 34: 193-202, 1969
18.Aigner D J, Goldberger A S (Eds.), *Latent variable in socioeconomic Models. Amsterdam : North Holland*1977
19.Goldberger A S, Duncan O D (eds), *Structural Equation Models in the Social Sciences. New York Seminar Press*1973
20.Johnston J J, *Econometric Methods (2nd ed.). New York : Mc Graw Hill*1972
21.Kmenta J, *Elements of Econometrics. New York: McMilan*1971
22.Kaliaperumal V G, Khalilian A R, Channabasavanna S M, [Structural Equations Models in child behaviour]
*NIMHANS Journal* Page: 12: 125-34, 1994
23.Bentler P M, Multivariate analysis with latent variables : Casual modeling
*Annual Review of Psychology* Page: 31: 419-56, 1988
24.Lesteler B M, Corwin M J, Sepkoski C, Seifer R, Peucker M, McLaughline, Goiub H L, Neurobehavioural syndromes in cocaine exposed newborn infants
*Child Development* Page: 62: 694-705, 1991
25.Everitt B S, *An Introduction to Latent Variable Models. New York. Chapman and hall*1984
26.Mardia K V, Measures of multivariate skewness and kurtosis with applications

*Biometrika* Page: 57; 519-30, 1970
27.McGee D L, A program for logistic regression on the IBM PC
*American Journal of Epidemiology* Page: 124: 702-5, 1986
28.Bentler P M, Bonett D G, Significance tests and goodness of fit in the analysis of covariance structure
*Psychological Bulletin* Page: 88: 588-606, 1988
29.Pertuiset B, Predictability of outcome in neurological survey
*Acta Neurochirugica* Page: 82: 73-91, 1986
30.Jennett B, Sneek J, Bond M R, Brooks N, Disability after severe head injury : Observations on the use of the Glasgow Coma Scale
*Journal of Neurology, Neurosurgery & Psychiatry* Page: 44: 285-93, 1981
31.Surgiura K, Muraoka K, Chischiki T, Baba M, (1983) The Edinburg-2 Coma Scale: A new scale for assessing impaired consciousness
*Neurosurgery* Page: 12: 411-5, 1983
32.Starmark J, Stalhammar D, Holmgren E, The reaction Level Scale (RLS 85). Manual and guidelines
*Acta Neurochirugica (Wein)* Page: 91: 12-20, 1988
33.Born J D, Albert A, Hans P, Bonnal J, Relative Prognostic value of the best motor response and brain stem reflexes in patients with severe head injury
*Neurosurgery* Page: 16: 595-601, 1985
34.Bruce D A, Schut L, Bruno L S, Wood J H, Sutton L N, Outcome following severe head injuries in children
*Journal of Neurosurgery* Page: 48: 679-88, 1978
35.Teasdale G, Parker L, Murray G, Knill R, Jennett B, Predicting the outcome of individual patients in the first week after severe head injury
*Acta Neurochirugica Suppl* Page: 28: 161-4, 1979
36.Nestvold K, Lundar T, Blikara G, Lonnum A, Head injuries during one year in a central hospital in Norway : A prospective study
*Neuroepidemiology* Page: 7: 134-44, 1988
37.Becker D P, Miller J D, Ward J D, Greenberg R P, Young J D, Sakalas R, The outcome from severe head injury with early diagnosis and intensive management
*Journal of Neurosurgery* Page: 47: 491-502, 1977
38.Carlsson C A, Von Essen C, Lofgren J, Factors affecting the clinical course of patients with severe head injuries. Part 1. Influence of biological factors. Part-2 : Significance of post-traumatic coma
*Journal of Neurosurgery* Page: 69: 242-51, 1968
39.Overgaard J, Christensen S, Prognosis after head injury based on early clinical examination
*Lancet* Page: ii: 631-5, 1973
40.McKenzie C F, Shin B, Fisher R, Two years morality in 760 patients transported by helicopter direct from the road accident scene
*American Journal of Surgery* Page: 45: 101-8, 1979
41.Narayan R K, Greenberg R P, Miller J D, Enas G G, Choi S C, Kishore P R S, Selhorst J B, Lutz H A, Becker D P, Improved confidence of outcome prediction in severe head injury
*Journal of Neurosurgery* Page: 54: 751-62, 1981
42.Warme P E, Bergstrom R, Persson L, Neurosurgical intensive care improves outcome after severe head injury
*Acta Neurochirugica* Page: 110; 57-64, 1991