Predicting outcome from closed head injury by early assessment of trauma severity

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The relationship between severity of head injury and outcome was studied in 96 patients. Severity was assessed based on the level of coma and presence of mass lesion, hemiparesis, skull fracture, and pupil abnormality. Outcome was assessed using the Wechsler Adult Intelligence Scale, the Halstead-Reitan neuropsychological battery, and the Glasgow Outcome Scale. The relationship between assessment of severity of trauma and the outcome measurements was calculated by multiple regression analysis. Results indicate that coma grade and estimates of premorbid intelligence quotient (IQ) served best to predict IQ as assessed after the injury. The combination of coma grade, mass lesion, and skull fracture were important predictors of the Halstead Impairment Index. Coma grade and pupil abnormality predicted the Glasgow Outcome Scale. Low to moderate relationships were found between the predictor variables and the measurement of IQ and the Glasgow Outcome Scale; multiple regression coefficients were 0.63 and 0.61, respectively. The relationship between measurement of trauma severity and the Halstead Impairment Index was also low (R = 0.37).

KEY WORDS □• severe head injury □• coma □• prognosis □• Grady Coma Scale □• Glasgow Outcome Scale

Previous studies of closed head injury have used many methods of measuring initial severity of trauma and outcome. Trauma severity has been measured by the presence of neurological release signs, hematoma, and skull fracture, as well as by the scaling of coma. Techniques of outcome assessment have ranged from simple mortality rate to cognitive, motor, and overall disability scales.

An early study by Ruesch found a relationship between duration of unconsciousness and the depression of cognitive functioning characterized by impairment of the ability to sustain attention and visual judgment. He found no difference in cognitive performance between 17 patients characterized as having severe head injury (three subdural hematomas, 10 skull fractures, and 10 cases of blood in the cerebrospinal fluid) and 53 patients with head injury who showed loss of consciousness as their only symptom.

Studies by Tooth and Klove and Cleeland revealed that the presence of abnormal neurological signs is related to duration of unconsciousness, disorientation, and cognitive outcome, while skull fracture was not found to be correlated to outcome. In a study of 27 cases, Levin, et al., found oculovestibular deficit and acute hemiparesis associated with poor intellectual outcome. Pupil abnormalities, skull fracture, and presence of hematoma were not found to be related to recovery. Levin, et al., also found duration of coma predictive of later aphasis signs. Individuals with coma of greater than 24 hours' duration showed greater deficits than those whose coma duration was less.

General outcome as assessed by the Glasgow Outcome Scale was found to be related to the Glasgow Coma Scale (GCS), increased intracranial pressure (ICP), pupil abnormality, midline shift, and patients' age. Of these measures, the GCS was the best predictor of later outcome. A number of studies have found the interval of confusion and memory loss present immediately postinjury (posttraumatic amnesia) inversely related to subsequent intellectual functioning. Brooks, et al., also found posttraumatic amnesia predictive of later intellectual outcome. However,
they found that duration of coma, site of hematoma, and skull fracture were not related to cognitive functioning. Posttraumatic amnesia is distinct from the other means of severity measurement because it is assessed during the early recovery phase and not at the time of injury.

Although the picture is by no means clear, poor cognitive outcomes have been shown to be associated with oculovestibular deficit, duration of coma, abnormal neurological signs, increased ICP, hemiparesis, and posttraumatic amnesia. Skull fracture, presence of hematoma, and pupil abnormalities were not found consistently predictive of later cognitive functioning. However, these studies of outcome have been criticized on methodological grounds. Few have used standardized measures of cognitive functioning or have adequately described their samples according to types and severity of injury. Few studies have adjusted for the interval between injury and time of testing; subjects were often tested at widely different points during their recovery. In the case of posttraumatic amnesia, severity of the trauma itself is vaguely defined and its measurement has not been supported by systematic reliability and validity studies.

Another criticism is that the studies use generally small samples of the more severe cases of head injury. Under these circumstances, any predictive relationship will be low because the variability in the predictors and criterion is constrained. Finally, no study has utilized multivariate prediction models in the data analysis. Most studies have used a comparison of mean differences on cognitive measures for groups differentiated by the presence or absence of a severity condition. A significant mean difference was taken as indicative of predictive power of the method of measuring trauma severity. Techniques for severity measurement are probably intercorrelated, and the unique contribution to prediction of these measures has not been assessed. Multivariate procedures allow for the assessment of both the unique predictive ability of each and the additive power from combining the separate measures.

The present study was designed to investigate the relationship of early measures of trauma severity to posttraumatic cognitive functioning assessed by standard tests. The study utilizes multiple regression procedures to analyze the relationships. This prediction model should aid in clarifying the unique contribution of trauma severity measures to outcome prediction.

Clinical Material and Methods

A series of 96 patients with closed head injury were administered a battery of neuropsychological tests after admission to the Medical Center Hospital of Vermont. The tests were given as part of their ongoing medical treatment. To be included in the study, all patients must have had sustained loss of consciousness for at least one-half hour after the time of their injury. Patients were tested early in the recovery phase, when they were oriented, could follow instructions, and had sufficient endurance to take neuropsychological tests. Patients were therefore excluded if they refused to take part or were so disabled by neurological or other dysfunction that they could not take the tests. The interval between injury and time of testing averaged 44 days, with a minimum of 11 days and a maximum of 180 days.

All subjects completed the Wechsler Adult Intelligence Scale (WAIS), but only 77 completed the full Halstead-Reitan battery of tests. Only patients who could be tested for the required 5 to 7 hours could receive the full Halstead-Reitan battery. The WAIS can be administered in approximately 1 hour. The summary measures derived from these tests and used in the present study were the Full Scale intelligence quotient (IQ) from the WAIS and the Halstead Impairment Index from the Halstead-Reitan battery. Patients who received the full battery did not differ significantly from the others in any of the demographic or injury severity measures used in the study. An estimate of premorbid Full Scale IQ based upon education, age, race, sex, and occupation was made using the equation provided by Wilson, et al. This equation was constructed by regressing predictor demographic variables on IQ, using the actual WAIS standardization sample. Thus, the premorbid Full Scale IQ test represents an estimate of IQ which is independent of any test measurement and based upon data collected solely from the history.

Most injuries were the result of motor-vehicle accidents (66%), with falls (22%) and miscellaneous accidents (12%) comprising the other causes of injury. Patients had a mean of 12.3 years of education and averaged 29 years of age. The sample contained 25 cases of mass lesion and 28 cases of skull fracture; 28 patients had hemiparesis at admission, and 21 demonstrated a pupil abnormality. The average time spent in the hospital was 30 days. The sample contained 69 men and 27 women.

The patients' level of coma was evaluated using the Grady Coma Scale. This scale is in widespread clinical use and has been shown to be highly correlated with other coma rating scales, such as the GCS. The rating was made in the context of the neurological evaluation performed in the emergency room at the time of injury. Global outcome was evaluated using the Glasgow Outcome Scale. This rating was made using information provided at the time of discharge.

The presence of pupil abnormality was noted if the subject had dilation of one or both pupils, or if the pupils were observed to be fixed and unresponsive to illumination. Hemiparesis was determined from the emergency room neurological examination which was administered at the time of injury. Presence of skull fracture was determined from radiological studies. The patient was considered to have a mass lesion if there existed an intracerebral or epidural hematoma which
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TABLE 1
Summary of regression analyses*

<table>
<thead>
<tr>
<th>Factors</th>
<th>Independent Variables</th>
<th>r</th>
<th>B</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>dependent variable: Full Scale IQ (FSIQ, R = 0.63)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>independent variables</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>premorbid Full Scale IQ (PMFSIQ)</td>
<td>0.45</td>
<td>0.8</td>
<td>29.1</td>
<td></td>
</tr>
<tr>
<td>coma level</td>
<td>−0.46</td>
<td>−4.8</td>
<td>30.5</td>
<td></td>
</tr>
<tr>
<td>(constant)</td>
<td>18.2</td>
<td>1.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FSIQ = 0.8(PMFSIQ) − 4.8(coma) + 18.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>dependent variable: Halstead Impairment Index (HII, R = 0.37)</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>independent variables</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>coma level</td>
<td>0.25</td>
<td>0.04</td>
<td>3.2</td>
<td></td>
</tr>
<tr>
<td>mass lesion†</td>
<td>0.27</td>
<td>0.16</td>
<td>3.8</td>
<td></td>
</tr>
<tr>
<td>skull fracture†</td>
<td>0.10</td>
<td>0.13</td>
<td>3.1</td>
<td></td>
</tr>
<tr>
<td>(constant)</td>
<td>0.25</td>
<td>2.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HII = 0.04(coma) + 0.16(mass lesion) + 0.13(skull fracture) + 0.25</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>dependent variable: Glasgow Outcome Scale (GOS, R = 0.61)</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>independent variables</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>coma level</td>
<td>0.58</td>
<td>0.36</td>
<td>39.4</td>
<td></td>
</tr>
<tr>
<td>pupil abnormality†</td>
<td>0.32</td>
<td>0.15</td>
<td>4.3</td>
<td></td>
</tr>
<tr>
<td>(constant)</td>
<td>0.98</td>
<td>45.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GOS = 0.36(coma) + 0.15(pupil abnormality) + 0.98</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* The multiple correlation (R) is exhibited in parenthesis after the dependent variable. The simple Pearson correlation is referred to as r. B weights are used to predict values of the dependent variable from raw scores.

† Mass lesion, skull fracture, and pupil abnormality: 0 = absent; 1 = present.

was verified by computerized tomography or surgical exploration. All these characteristics were noted at the time of injury.

To evaluate the ability of a combination of early measures of trauma severity to predict later cognitive and global outcome, the variables were entered into stepwise regression analysis with the WAIS Full Scale IQ, the Halstead Impairment Index, and the Glasgow Outcome Scale as dependent measures. Regression analysis determines the group of predictor variables that best predict the dependent measure. Variables are entered into the analysis in stepwise fashion with the variable accounting for the most variance in the dependent measured being entered first. Successive variables are entered which then account for most of the remaining variance. This process is continued until the greatest amount of variance is accounted for in the dependent variable. The final result is a prediction equation which represents the linear relationship between the set of predictors and the criterion. An added feature is that predictor variables which are redundant and do not uniquely predict the dependent variable are excluded from the final equation. This equation therefore represents a parsimonious prediction of the dependent variable. Variables were not included in the prediction equation if they did not increase the explained variance by at least 1%.

As illustrated in Table 1 and Fig. 1, Full Scale IQ assessed after the injury is predicted moderately well by the premorbid estimate of Full Scale IQ and the coma grade evaluated by the Grady Coma Scale. The Halstead Impairment Index is predicted by the coma grade and presence of mass lesion and skull fracture. The relationship is low, however, with explained variance at approximately 14%. The Glasgow Outcome Scale is moderately well predicted by the variables: coma grade and pupil abnormality.

The equations provided in Table 1 can be used to predict the outcome in new cases of head injury. In the case of Full Scale IQ, the standard error of estimate is 12.7 when coma grade and premorbid performance IQ are used as predictors. This means that for the present sample, 68% of the predicted IQ scores fell within 13 points of the actual IQ scores.

Discussion

Previous research has recognized that coma level, pupil abnormality, and mass lesion were important measures of trauma severity and could predict recovery from closed head injury to some extent. This study clarifies the degree and type of predictive relationship.

In general, coma grading appears to be the best predictor of general cognitive functioning after the injury. Presence of mass lesion, pupil abnormality, and skull fracture provides largely redundant information.
These other measures do have some predictive power, but this is overshadowed by the strong predictive ability of coma grade.

Premorbid estimates of IQ also predict cognitive functioning assessed after the injury. Although this relationship is often assumed in clinical practice, it has been largely neglected by researchers. Such estimates approach the importance of coma grade as predictors of cognitive functioning.

The results also highlight a feature of the Halstead tests as early outcome measures. The severity measures are not strongly predictive of the Halstead Impairment Index because it is strongly skewed toward impairment. In contrast to the WAIS, the Halstead tests are apparently very sensitive to impairment and most individuals who suffer any level of brain injury demonstrate impairment on these tasks. This constrains the degree of association between this summary measurement and the trauma severity measures. Later in the recovery phase, the Halstead Impairment Index may be better predicted because its variance will increase.

An important feature of this study is that outcome was assessed early in the recovery phase and the results must be considered with this in mind. Hence, severity measures may be more predictive of outcome because intervening events such as cognitive retraining, better psychological adjustment to the disability, and the like have not yet exerted their influence on outcome. Future research is needed to clarify the predictive ability of these early indicators of trauma severity and more long-term follow-up results.

Another qualifying aspect of these results is that patients were only included in the study if they were able to take neuropsychological tests. Many severe cases of head injury are not included because of early mortality or extreme cognitive and physical disabilities. Perhaps the predictive ability of the measurements of severity of trauma could be further clarified if such outcomes were taken into consideration. For example, if most individuals who suffer a mass lesion die or have some extreme neurological deficit which precludes testing, mass lesion will not appear generally predictive of cognitive functioning as measured by standard tests.

From a clinical point of view, the study provides equations that can be used to predict outcome in future cases. Although the predictive power of these equations is only moderate, they provide for the most accurate empirical prediction so far possible. It is apparent from these results that knowledge of coma level and premorbid IQ are all that is needed to make such predictions of postinjury cognitive abilities. Of course, the utility of these prediction equations must be qualified by future cross-validation studies.

In conclusion, this study illustrates the predictive validity of early assessment of severity. Of the variables studied, estimates of premorbid IQ and coma grade were most important in predicting outcome. A combination of predictor variables served to explain approximately 40% of the variation in two of the outcome measures. With the regression equations provided, empirical estimates of postinjury outcome can be made. The study demonstrates that early cognitive and global outcome can be reasonably well predicted from initial injury severity and from estimates of premorbid functioning.

References

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