Does head CT scan pathology predict outcome after mild traumatic brain injury?

M. Lannsjo\textsuperscript{a,b}, M. Backheden\textsuperscript{c}, U. Johansson\textsuperscript{b}, J. L. af Geijerstam\textsuperscript{d} and J. Borg\textsuperscript{e}

\textsuperscript{a}Department of Rehabilitation Medicine, Institute of Neuroscience, University of Uppsala, Uppsala, Sweden; \textsuperscript{b}Centre for Research and Development, Uppsala University/County Council of Gävleborg, Gävleborg, Sweden; \textsuperscript{c}Medical Statistics Unit, Department LIME, Karolinska Institutet, Stockholm, Sweden; \textsuperscript{d}Clinical Epidemiology Unit, Department of Medicine, Karolinska Institutet, Stockholm, Sweden; and \textsuperscript{e}Department of Clinical Sciences, Rehabilitation Medicine, Karolinska Institutet, Danderyd Hospital, Stockholm, Sweden

Keywords: brain concussion, head CT scan, mild traumatic brain injury, prediction

Background: More evidence is needed to forward our understanding of the key determinants of poor outcome after mild traumatic brain injury (MTBI). A large, prospective, national cohort of patients was studied to analyse the effect of head CT scan pathology on the outcome.

Methods: Thousand two hundred and sixty-two patients with MTBI [Glasgow Coma Scale (GCS) score 15] at 39 emergency departments completed a study protocol including acute head CT scan examination and follow-up by the Rivermead Post Concussion Symptoms Questionnaire (RPQ) and the Glasgow Outcome Scale Extended (GOSE) at 3 months after MTBI. Binary logistic regression was used for the assessment of prediction ability.

Results: In 751 men (60%) and 511 women (40%), with a mean age of 30 years (median 21, range 6–94), we observed relevant or suspect relevant pathologic findings on acute CT scan in 52 patients (4%). Patients aged below 30 years reported better outcome both with respect to symptoms and GOSE as compared to patients in older age groups. Men reported better outcome than women as regards symptoms (OR 0.64, CI 0.49–0.85 for ≥2 symptoms) and global function (OR 0.60, CI 0.39–0.92 for GOSE 1–6).

Conclusions: Pathology on acute CT scan examination had no effect on self-reported symptoms or global function at 3 months after MTBI. Female gender and older age predicted a less favourable outcome. The findings support the view that other factors than brain injury deserve attention to minimize long-term complaints after MTBI.

Introduction

Traumatic brain injury (TBI) is a recognized public health problem with annual incidence rates around 250 per 100 000 or more [1,2]. Most patients have a mild TBI with a presenting Glasgow Coma Scale (GCS) score of 13–15 [3]. A majority of these patients present with a GCS score of 15 [4] and are clinically diagnosed with a brain concussion.

Evidence-based guidelines for the acute management of patients with mild TBI (MTBI) specify criteria for routine use of CT scan examination as part of the diagnostic set-up [5,6]. In patients presenting with a GCS score of 15, around 5% exhibits trauma-related CT scan abnormalities [7,8] and acute CT scan examination allows safe and cost-effective triage of this large MTBI population [9].

In contrast, evidence-based guidelines for cost-effective prevention and treatment of post-traumatic, ‘post-concussional’ problems are lacking, although such problems have long been recognized in a subgroup of patients [10,11]. Some evidence indicates that early, educational information [12,13] and team-based follow-up [14] may be beneficial but identification of patients at risk for poor outcome remains a challenge. Whilst previous studies of patients with MTBI have demonstrated that older age [15,16], female gender [17], premorbid health problems [18,19], co-morbidities [19,20] and other injuries [16,18], financial incentives and litigation [21,22], may be associated with poor outcome, the impact of brain lesions remains unclear and a matter of debate.

Keywords: brain concussion, head CT scan, mild traumatic brain injury, prediction
Two recent studies indicate that demographic and other variables [16,18] are stronger predictors than CT scan pathology. These studies included patients seen at a level I Trauma centre and presenting with a GCS score of 13–15. More evidence is needed to forward our understanding of the key determinants of poor outcome after MTBI and thus identify relevant targets for preventive and therapeutic interventions and to guide clinical management. Patients with the mildest form of MTBI, who present with a GCS score of 15, constitute the largest proportion of all patients with TBI and are managed in both regional and local hospitals. Hence, using acute head CT scan examination, we investigated the effect of traumatic pathology on the outcome after MTBI in a large, prospective national cohort of patients with MTBI and a presenting GCS score of 15.

Methods

During the period May 2001–January 2004, 39 of 75 emergency departments in Sweden participated in a randomized controlled trial comparing effects and costs of two acute management strategies for MTBI [9]. Participating departments were representative according to hospital size and geographical distribution. Eligible were patients ≥6 years and with a history of head trauma within the last 24 h, confirmed or suspected loss of consciousness (LOC) and/or amnesia, normal neurological examination and a GCS score of 15, and no associated injuries that required admission. A total of 2602 persons were recruited and randomized either to inpatient care (1286) or to head CT scan and discharge if CT findings were normal (1316). Patients, who were randomized to head CT scan and discharge, formed the study sample. Scans were reported and interpreted according to local clinical practice at each study site.

Follow-up at 3 months post-injury was by mailed questionnaires to assess symptoms outcome by the Rivermead Post Concussion Symptoms Questionnaire (RPQ) [25] and global outcome by the Glasgow Outcome Scale Extended (GOSE) [26,27].

The RPQ consists of 16 items asking the patient to rate symptoms on a scale from 0 to 4 (0 = not experienced at all, 1 = no more of a problem, 2 = a mild problem, 3 = a moderate problem and 4 = a severe problem). Questionnaires were received from 97% of the participants. Frequency of missing data in the questionnaires was <1.5% for each of the 16 items. Poor symptom outcome was defined as three symptoms or more according to RPQ. We also analysed outcome of symptoms belonging to each of four factors (somatic, cognitive, emotional and audio-visual) identified in a previous study [28].

The GOSE is an ordinal scale with eight steps (1 = dead, 2 = vegetative state, 3 = lower severe disability, 4 = upper severe disability, 5 = lower moderate disability, 6 = upper moderate disability, 7 = lower good recovery, 8 = upper good recovery).

Statistical methods

Binary logistic regression was used to analyse data. Predictor variables in the statistical models were findings at head CT scan, age and gender. Outcome variables were GOSE score dichotomized to 1–6 and 7–8 and RPQ reporting dichotomized into having or not having ≥3 symptoms. Age was entered in the model as a factor with the age groupings, 6–14.9, 15–29.9, 30–59.9, 60–79.9 and ≥80 years. Pair wise comparisons between age groups were performed in case of a significant overall age effect. The overall model was checked with tests of the global null hypothesis. Type 3 analyses for each predictor variable were carried out as well as odds ratios with 95% confidence intervals. The type 3 analysis gives a result that is independent of the variables order in the model. A significance level of 5% was used for all tests performed. Binary logistic regression model fit was assessed with the Hosmer Lemeshow test. The area under the Receiver Operating Characteristic Curve (ROC curve), AUC, was calculated to estimate discrimination ability. Bivariate associations were assessed with Spearman rank correlation and log linear models. The statistical analyses were carried out in the statistical package SAS 9.2 (SAS Institute Inc., Solna, Sweden).

Ethics

No financial incentives were offered. Oral and written information was provided for written consent. All regional research ethics committees in Sweden approved the study. The Swedish national health and pharmaceutical insurance plan covered all patients included in the study.

Results

The study sample comprised 1262 patients, 751 men (60%) and 511 women (40%) after exclusion of 24 patients with missing head CT scan data and 30 with pathology on CT scan not associated with the acute injury. Table 1 presents baseline data.

Mean age was 30 years (median, 21; range, 6.0–93.6). The sample was divided into five age groups (Table 1) according to homogenous frequencies of symptoms.
within these groups. Relevant or suspected relevant pathology was observed in 52 of 1262 (4%) CT scans and comprised haemorrhage/contusions in 27 (52%), fractures in 10 (19%), haematomas in 7 (14%), oedema or other in 8 (15%). We found no significant interactions between gender and CT results or between age and gender.

Effect of age, gender and CT pathology on symptoms at 3 months post-injury

Poor symptom outcome was defined as reporting ≥3 symptoms. When individual symptoms were dichotomized into no current problems with symptoms (RPQ scores 0–1) versus little, moderate or severe problems with symptoms (RPQ scores 2–4), 23% (n = 279) of the participants reported three or more symptoms after 3 months (6% missing data). All symptoms except double-vision showed satisfying likelihood ratio. However, “double vision” had no significant influence on the results and was kept in the analysis. Table 2 presents results of the binary logistic regression analysis.

Age had an effect on symptoms at 3 months. Patients in age groups below 30 years had significantly lower OR for reporting three or more symptoms. Gender also had an effect. Males had significantly lower OR for reporting three or more symptoms. Head CT scan results had no effect on symptom outcome (Table 2). Area under the ROC curve was 0.654.

Effects on symptoms by symptom factors

Somatic, cognitive, emotional or audio-visual factors, respectively, were examined for two levels of unfavourable outcome, that is, one symptom or more and two symptoms or more, respectively. The results of these analyses corresponded well to the results of the analysis for all symptoms and added no more information.

Effect of age, gender and CT pathology on global function at 3 months post-injury

At 3 months, four patients (0.3%) had a score of 1 (dead), no patient had a score of 2 (vegetative state), 101 had a score of 1–6 (8%) and 1125 had a GOSE score 7–8 (89%); data were missing in 3%. Good outcome was defined as GOSE scores of 7–8 and poor outcome as GOSE scores of 1–6. Table 3 presents the results of the binary regression analysis.

Age had an effect on GOSE at 3 months with in the main, significantly lower OR for poor outcome for younger ages compared to older. We found no significant differences between the two youngest age groups (6–14.9 and 15–29.9), between age groups 15–29.9 and 30–59.9 and between age group 30–59.9 and 60–79.9. Gender also had an effect. Men had significantly lower OR for a poor outcome. Head CT scan results had no effect on the outcome according to GOSE. Area under the ROC curve was 0.669.

Analyses with Spearman rank correlations showed no significant correlations between GOSE scores and remaining symptoms (correlation value 0.14).

Discussion

The main finding of this study is that traumatic head CT scan pathology has no effect on self-reported outcome at 3 months after MTBI. Study patients had a presenting GCS score of 15 in the emergency room, and thus represent the largest subgroup of patients

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Table 1 Age, gender and result of head CT scan

<table>
<thead>
<tr>
<th>Base Line data</th>
<th>% (No.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
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<tr>
<td>6–14.9</td>
<td>32 (394)</td>
</tr>
<tr>
<td>15–29.9</td>
<td>31 (389)</td>
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<tr>
<td>30–59.9</td>
<td>24 (304)</td>
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<tr>
<td>60–79.9</td>
<td>10 (128)</td>
</tr>
<tr>
<td>≥80</td>
<td>3 (39)</td>
</tr>
<tr>
<td>Gender</td>
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</tr>
<tr>
<td>Male</td>
<td>60 (751)</td>
</tr>
<tr>
<td>Female</td>
<td>40 (511)</td>
</tr>
<tr>
<td>CT</td>
<td></td>
</tr>
<tr>
<td>Normal</td>
<td>96 (1210)</td>
</tr>
<tr>
<td>Pathology, total</td>
<td>4 (52)</td>
</tr>
<tr>
<td>Haemorrhage/contusion</td>
<td>(27)</td>
</tr>
<tr>
<td>Haematoma</td>
<td>(10)</td>
</tr>
<tr>
<td>Fracture, no other pathology</td>
<td>(7)</td>
</tr>
<tr>
<td>Oedema/other</td>
<td>(8)</td>
</tr>
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</table>

Table 2 Effect of age, gender and CT scan pathology on symptoms at 3 months after mild traumatic brain injury. The table shows regards symptoms (OR) for having problems with three or more symptoms (poor outcome)

<table>
<thead>
<tr>
<th>Factor</th>
<th>Comparison</th>
<th>OR</th>
<th>95% CI Lower</th>
<th>95% CI Upper</th>
<th>P-value</th>
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<td>Age</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6.0–14.9</td>
<td>15.0–29.9</td>
<td>0.52</td>
<td>0.35</td>
<td>0.77</td>
<td>0.001</td>
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<td>6.0–14.9</td>
<td>30.0–59.9</td>
<td>0.30</td>
<td>0.20</td>
<td>0.44</td>
<td>0.000</td>
</tr>
<tr>
<td>6.0–14.9</td>
<td>60.0–79.9</td>
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<td>0.19</td>
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</tr>
<tr>
<td>6.0–14.9</td>
<td>80.0–99.9</td>
<td>0.22</td>
<td>0.10</td>
<td>0.47</td>
<td>0.000</td>
</tr>
<tr>
<td>15.0–29.9</td>
<td>30.0–59.9</td>
<td>0.58</td>
<td>0.41</td>
<td>0.82</td>
<td>0.002</td>
</tr>
<tr>
<td>15.0–29.9</td>
<td>60.0–79.9</td>
<td>0.62</td>
<td>0.39</td>
<td>0.98</td>
<td>0.041</td>
</tr>
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<td>15.0–29.9</td>
<td>80.0–99.9</td>
<td>0.42</td>
<td>0.20</td>
<td>0.88</td>
<td>0.022</td>
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<tr>
<td>30.0–59.9</td>
<td>60.0–79.9</td>
<td>1.07</td>
<td>0.67</td>
<td>1.70</td>
<td>0.772</td>
</tr>
<tr>
<td>30.0–59.9</td>
<td>80.0–99.9</td>
<td>0.73</td>
<td>0.35</td>
<td>1.53</td>
<td>0.411</td>
</tr>
<tr>
<td>60.0–79.9</td>
<td>80.0–99.9</td>
<td>0.69</td>
<td>0.31</td>
<td>1.51</td>
<td>0.352</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Male/Female</td>
<td></td>
<td>0.64</td>
<td>0.49</td>
<td>0.85</td>
<td>0.002</td>
</tr>
<tr>
<td>CT</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Normal/Pathologic</td>
<td></td>
<td>0.68</td>
<td>0.36</td>
<td>1.32</td>
<td>0.24</td>
</tr>
</tbody>
</table>
with traumatic brain injuries [4]. Patients from different hospital settings were included, and the attrition rate was low. Hence, the findings add to our understanding of outcome prediction after MTBI and support the view that factors other than brain injury, as defined by head CT scan pathology, are key predictors. The findings also indicate that more sensitive methods than CT scan are needed to detect relevant brain abnormalities in this group of patients.

We defined a poor symptoms outcome as a report of three symptoms or more, which is in accordance with most previous studies and suggested criteria sets for related ICD-10 and DSM IV diagnoses [29,30]. Outcome was measured at 3 months after the event because previous studies indicate that when symptoms resolve after MTBI, this occurs within this time-period [22] and the risk for intervening events that may confound the outcome increases by time. The proportion of patients with a poor symptoms outcome (23%) is in agreement with previous reports, although some studies including patients within the whole MTBI spectrum report larger proportions [19,23,31,32]. The RPQ symptoms questionnaire is a widely used measure that has recently been subject to factor analysis [28,33] and Rasch analysis [34,35]. Based on findings in these previous studies, we dichotomized data for each symptom (having or not having symptoms) instead of using total, summary scores.

Glasgow Outcome Scale Extended is an established instrument to assess global outcome after TBI, covers aspects on personal care and social functioning and relates consistently with other measures of self-reported health and disability [27]. We defined poor outcome as a GOSE score of 1–6, which complies with the instructions of the scale a recent study in the area [16]. The observed proportion of patients reporting a GOSE score below 7 (8%) was lower than reported in some previous studies including patients with GCS scores of 13–15 [15,16].

The rate of relevant or suspect relevant pathology on head CT scan was 4%, most of which was attributed to haemorrhage or brain contusion. The CT scan results rely on routine evaluation by radiologists at each of the hospitals where patients were recruited, and consequently, the validity of these data may be questioned. However, the observed frequency and type of CT scan abnormalities are in agreement with previous reports on patients presenting with a GCS score of 15 [8], but lower than observed in more selected study samples recruited at trauma-level centres [16,36]. Thus, the CT scan findings reflect routine evaluation of these patients in clinical practice and give our results high external validity. This information should form the basis on which to guide patients and plan further interventions.

CT scan pathology had no effect on self-reported symptoms in total, or on somatic, cognitive, emotional or audio-visual symptoms as previous defined by factor analysis [28,33]. This does not exclude brain pathology as a factor at play in patients with a poor outcome after MTBI. First, our study allows conclusions only for patients presenting with a GCS score of 15, and with no need of surgical or other specific interventions. However, these patients constitute the large majority of patients with MTBI, or brain concussion [4]. Second, CT scans may not be sensitive to relevant functional or structural abnormalities, for example, diffuse axonal injury [37]. Some previous studies indicate that a substantial proportion of patients with MTBI and a normal head CT scan might have brain pathology according to MRI scans [38] but the impact of such brain pathology on the long-term outcome after MTBI remains to be

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Table 3 Effect of age, gender and CT scan pathology on Glasgow Outcome Scale Extended (GOSE) at 3 months. The table shows regards symptoms (OR) for having a GOSE score of 1–6 (poor outcome)

<table>
<thead>
<tr>
<th>Factor</th>
<th>Comparison</th>
<th>OR</th>
<th>95% CI</th>
<th>Lower</th>
<th>Upper</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>6.0–14.9</td>
<td>15.0–29.9</td>
<td>0.65</td>
<td>0.35</td>
<td>1.23</td>
<td>0.194</td>
</tr>
<tr>
<td>Gender</td>
<td>Male/Female</td>
<td>0.60</td>
<td>0.39</td>
<td>0.92</td>
<td>0.018</td>
<td></td>
</tr>
<tr>
<td>CT</td>
<td>Normal/Pathologic</td>
<td>0.52</td>
<td>0.23</td>
<td>1.16</td>
<td>0.114</td>
<td></td>
</tr>
</tbody>
</table>

*Overall test for age, P < 0.001.
demonstrated. Thus, further studies, utilising new neuroimaging methods, will hopefully clarify the possible role of structural or functional abnormalities for long-term outcome after the most common, mildest injuries [39]. Third, although clinically relevant, self-reported outcomes might not be very specific, and no consensus has yet been reached on how to define a poor outcome [24].

The impact of age and gender on the outcome after MTBI has been subject to several previous studies. Most previous reports on the impact of age indicate that young persons have better outcome [15,16,22]. The present study provides strong evidence that age has an effect on the self-reported outcome after MTBI and that young persons have a better outcome. Most previous reports on the impact of gender indicate that women report more remaining symptoms after MTBI than men are. The present study provides strong evidence that gender has an effect on self-reported outcome after MTBI and that women are at greater risk for poor outcome than men are.

The key finding of this study has some practical implications. There is some evidence that the early provision of educational and reassuring information as well as team-based follow-up may reduce long-term problems after MTBI [8,12–14]. Our findings indicate that a similar approach is relevant also for patients presenting with a GCS score of 15 after blunt head trauma and with head CT scan abnormalities that do not require surgery or other acute intervention. Instead, pre-injury factors, co-morbidities and social problems deserve more attention and some of these may be available for intervention. Further studies with other diagnostic tools including new brain imaging methods [39] may help clarify the potential role of abnormal brain function or structure for persisting problems and if these may be targeted by MTBI-specific treatments.

Limitations of study

The study design did not allow control for other relevant baseline factors, for example, psychosocial conditions or co-morbidities, or for intervening events or interventions during the follow-up period. However, we controlled for two strong predictors identified also in previous studies, and it appears less likely that other factors would change the main finding. The predictor variables discrimination ability, as assessed by the estimated AUC, was only modest, which probably reflects the difficulty to find strong predictors in a complexity of causes in this context.

Conclusions

Acute head CT scan pathology does not predict symptoms or global function at 3 months after MTBI with a presenting GCS score of 15, but female gender and older age are associated with poor outcome. The findings support the view that factors other than brain injury deserve attention to minimize long-term complaints after MTBI and also that more sensitive imaging methods than CT scan are needed to clarify the possible impact of brain abnormalities on long-term outcome after MTBI.

Acknowledgements

Grants from the Centre for Research and Development Uppsala University/County Council of Gävleborg, the Stockholm County Council and AFA Insurance. Authors declare no conflicts of interest.

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