MRC CRASH Trial Collaborators; Perel, P; Arango, M; Clayton, T; Edwards, P; Komolafe, E; Pocock, S; Roberts, I; Shakur, H; Steyerberg, E; Yutthakasemsunt, S (2008) Predicting outcome after traumatic brain injury: practical prognostic models based on large cohort of international patients. BMJ, 336 (7641). pp. 425-9. ISSN 1468-5833 DOI: 10.1136/bmj.39461.643438.25

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Predicting outcome after traumatic brain injury: practical prognostic models based on large cohort of international patients

MRC CRASH Trial Collaborators

ABSTRACT

Objective To develop and validate practical prognostic models for death at 14 days and for death or severe disability six months after traumatic brain injury.

Design Multivariable logistic regression to select variables that were independently associated with two patient outcomes. Two models designed: “basic” model (demographic and clinical variables only) and “CT” model (basic model plus results of computed tomography). The models were subsequently developed for high and low-middle income countries separately.

Setting Medical Research Council (MRC) CRASH Trial.

Subjects 10 008 patients with traumatic brain injury. Models externally validated in a cohort of 8509.

Results The basic model included four predictors: age, Glasgow coma scale, pupil reactivity, and the presence of major extracranial injury. The CT model also included the presence of petechial haemorrhages, obliteration of the third ventricle or basal cisterns, subarachnoid bleeding, midline shift, and non-evacuated haematoma. In the derivation sample the models showed excellent discrimination (C statistic above 0.80). The models showed good calibration graphically. The Hosmer-Lemeshow test also indicated good calibration, except for the CT model in low-middle income countries. External validation for unfavourable outcome at six months in high income countries showed that basic and CT models had good discrimination (C statistic 0.77 for both models) but poorer calibration.

Conclusion Simple prognostic models can be used to obtain valid predictions of relevant outcomes in patients with traumatic brain injury.

INTRODUCTION

Traumatic brain injury is a leading cause of death and disability worldwide. Every year, about 1.5 million affected people die and several millions receive emergency treatment.1 2 Most of the burden (90%) is in low and middle income countries.3

Clinicians treating patients often make therapeutic decisions based on their assessment of prognosis. According to a 2005 survey, 80% of doctors believed that an accurate assessment of prognosis was important when they made decisions about the use of specific methods of treatment such as hyperventilation, barbiturates, or mannitol.4 A similar proportion considered that this was important in deciding whether or not to withdraw treatment. Assessment of prognosis was also deemed important for counselling patients and relatives. Only a third of doctors, however, thought that they accurately assessed prognosis.4

Prognostic models are statistical models that combine data from patients to predict outcome and are likely to be more accurate than simple clinical predictions.5 The use of computer based prediction of outcome in patients with traumatic brain injury increases the use of certain therapeutic interventions in those predicted to have a good outcome and reduces their use in those predicted to have a poor outcome.6

Many prognostic models have been reported but none are widely used. A recent systematic review offers possible explanations.7 Most models were developed on small samples, most were methodologically flawed, and few were validated in external populations. Few were presented in a clinically practical way, nor were they developed in populations from low and middle income countries, where most trauma occurs.

The Medical Research Council (MRC) CRASH (corticosteroid randomisation after significant head injury) trial is the largest clinical trial conducted in patients with traumatic brain injury and presents a unique opportunity to develop a prognostic model.8 9 The trial prospectively included patients within eight hours of the injury, used standardised definitions of variables, and achieved almost complete follow-up at six months. Furthermore, the large sample size guarantees precise and valid predictions. The high recruitment of patients from low and middle income countries means that models developed with these data are relevant to these settings.

We have developed and validated prognostic models for death at 14 days and death and disability at six months in patients with traumatic brain injury.

METHODS

Patients—The study cohort was all 10 008 patients enrolled in the trial. Adults with traumatic brain injury, who had a score on the Glasgow coma scale of 14 or
less, and who were within eight hours of injury, were eligible for inclusion in the trial.

Outcomes—Death of a patient was recorded on an early outcome form that was completed at hospital discharge, death, or 14 days after randomisation (whichever occurred first). Unfavourable outcome (death or severe disability) at six months was defined with the Glasgow outcome scale (see box). The scale comprises five categories: death, vegetative state, severe disability, moderate disability, and good recovery. For the purpose of this analysis, we dichotomised outcomes into favourable (moderate disability or good recovery) and unfavourable (dead, vegetative state, or severe disability).10

Prognostic variables—For the prognostic model we considered age, sex, cause of injury, time from injury to randomisation, Glasgow coma score at randomisation, pupil reactivity, results of computed tomography, whether the patient had sustained a major extracranial injury, and level of income in country (high or low-middle income countries, as defined by the World Bank) (see table A on bmj.com).11 We adjusted analyses for treatment within the trial as this was related to outcome, and we did not find interaction between treatment and the potential predictors.8,9

Analysis—Most of the variables collected in the CRASH trial have been previously associated with prognosis in traumatic brain injury, so we included all of them in a first multivariable logistic regression analysis.12 We excluded variables that were not significant at 5% level. We quantified each variable’s predictive contribution by its z score (the model coefficient divided by its standard error). We explored linearity between age and mortality at 14 days and Glasgow coma score and mortality at 14 days. Interactions between country income level and all the other predictors were evaluated with a likelihood ratio test. Because there were few data missing, we performed a complete case analysis.

Prognostic models—We developed different models for each of the two outcomes: a basic model, which included only clinical and demographic variables, and a CT model, which also included results of computed tomography.

Performance of the model—We assessed performance of the models in terms of calibration and discrimination. Calibration was assessed graphically and with the Hosmer-Lemeshow test. Discrimination was assessed with the C statistic (an equivalent concept to area under the receiver operator characteristic curve).13

Internal validation—The internal validity of the final model was assessed by the bootstrap re-sampling technique. Regression models were estimated in 100 models. For each of 100 bootstrap samples we refitted and tested the model on the original sample to obtain an estimate of predictive accuracy corrected for bias. This showed no overoptimism in any of the final model’s predictive C statistics.

External validation—A good prognostic model should be generalisable to populations different to those in which it was derived.14 We externally validated the models in an external cohort of 8509 patients with moderate and severe traumatic brain injury from 11 studies conducted in high income countries (the IMPACT (international mission for prognosis and clinical trial) dataset).15

Score development—We developed a clinical score based on regression coefficients. A web based version of the model was developed to be accessible to clinicians internationally.
RESULTS

General characteristics

Table 1 shows the characteristics of the patients. More of the patients were men (81%) and more came from low-middle income countries (75%). More than half (58%) of participants were included within three hours of injury. Road traffic crashes were the most common cause of injury (65%) and 79% of the participants underwent computed tomography. A total of 1948 patients (19%) died in the first two weeks, 2323 patients (24%) were dead at six months, and 3556 patients (37%) were dead or severely dependent at six months.

The relation between age and the log odds of death within 14 days showed no association until the age of 40 and a linear increase afterwards. The relation between Glasgow coma score and mortality at 14 days was reasonably linear and we therefore included the coma score as a continuous variable (figs 1 and 2). The relation with unfavourable outcome at six months showed similar patterns.

Low-middle v high income countries

In comparison with patients from high income countries, those from low-middle income countries were younger, more likely to be male, were recruited later, had less severe traumatic brain injury (as defined by Glasgow coma score and pupil reactivity), and more often had abnormal results on computed tomography. Road traffic crashes were a more common cause of traumatic brain injury. Although patients from low-middle income countries experienced higher mortality at 14 days (odds ratio 1.94, 95% confidence interval 1.64 to 2.30), there was no significant difference in unfavourable outcome at six months.

There were significant interactions between the country’s income level and several predictors and so we developed two models, one for low-middle income countries and another for high income countries. Older age was a stronger predictor of 14 day mortality in high income countries (interaction P<0.001), and lower Glasgow coma score was a stronger predictor in low-middle income countries (interaction P<0.001), and lower Glasgow coma score was a stronger predictor in low-middle income countries (interaction P<0.001), and lower Glasgow coma score was a stronger predictor in low-middle income countries (interaction P<0.001), and lower Glasgow coma score was a stronger predictor in low-middle income countries (interaction P<0.001).

Obliteration of the third ventricle and a non-evacuated haematoma were both associated with a higher risk in high income countries (interaction P<0.001 and P<0.03, respectively).

Multivariable predictive models

We developed eight models altogether: basic and CT models for predicting two outcomes in two settings (low-middle and high income countries).

Basic models—We included four predictors in the basic model: age, Glasgow coma score, pupil reactivity, and the presence of major extracranial injury (table 2). Glasgow coma score was the strongest predictor of outcome in low-middle income countries and age was the strongest predictor in high income countries, while the absence of pupil reactivity was the third strongest predictor in both regions.

CT models—The following characteristics on computed tomography were strongly associated with the outcomes in addition to the predictors included in the basic models: presence of petechial haemorrhages, obliteration of the third ventricle or basal cisterns, subarachnoid bleeding, midline shift, and non-evacuated haematoma (table 3). Obliteration of the third ventricle and midline shift were the strongest predictor in both regions.

Table 1 | General characteristics of study population

<table>
<thead>
<tr>
<th align="left">Age (years):</th>
<th>Total (n=10 008)</th>
<th>Low-middle income countries (n=7 526)</th>
<th>High income countries (n=2 482)</th>
<th>P value*</th>
</tr>
</thead>
<tbody>
<tr>
<td align="left">&lt;20</td>
<td>12.3</td>
<td>12.5</td>
<td>11.8</td>
<td></td>
</tr>
<tr>
<td align="left">20-24</td>
<td>17.0</td>
<td>17.8</td>
<td>14.4</td>
<td></td>
</tr>
<tr>
<td align="left">25-29</td>
<td>13.0</td>
<td>13.5</td>
<td>11.2</td>
<td></td>
</tr>
<tr>
<td align="left">30-34</td>
<td>10.7</td>
<td>10.9</td>
<td>10.1</td>
<td></td>
</tr>
<tr>
<td align="left">35-44</td>
<td>17.9</td>
<td>18.5</td>
<td>15.9</td>
<td></td>
</tr>
<tr>
<td align="left">45-54</td>
<td>12.5</td>
<td>12.3</td>
<td>13.3</td>
<td></td>
</tr>
<tr>
<td align="left">≥55</td>
<td>16.7</td>
<td>14.5</td>
<td>23.4</td>
<td></td>
</tr>
<tr>
<td align="left">Mean (SD)</td>
<td>37 (17.1)</td>
<td>35.8 (16)</td>
<td>40.6 (19.4)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Sex:
- Female 19.0 18.3 21.1 0.002
- Male 81.0 81.7 78.9

Hours since injury:
- ≤1 26.8 24.0 35.2
- 1-3 31.0 30.1 33.7
- >3 42.3 45.9 31.1
- Mean (SD) 3.4 (2.7) 3.6 (2.8) 2.8 (2.0) <0.001

Cause of head injury:
- Road traffic crash 65.1 69.9 50.2 <0.001
- Fall >2 meters 13.3 11.1 20.0
- Other 21.7 19.0 29.8

Total Glasgow coma score:
- Mild (3-14) 30.2 29.4 32.6 <0.001
- Moderate (9-12) 30.4 32.6 23.6
- Severe (3-8) 39.5 38.0 43.8

Pupil reactivity:
- Both reactive 82.8 83.5 80.7 <0.001
- One reactive 6.3 6.2 6.3
- None reactive 8.2 8.0 9.1
- Unable to assess 2.7 2.3 3.9

Major extracranial injury:
- No 77.3 77.3 77.5 0.801
- Yes 22.7 22.7 22.5

Computed tomography:
- No scan 21.1 24.0 12.0 <0.001
- Normal scan 22.8 20.0 30.2 <0.001
- Petechial haemorrhages 28.7 28.7 28.7 0.970
- Obliteration of 3rd ventricle or basal cisterns 23.4 28.6 9.6 <0.001
- Subarachnoid bleed 31.6 33.5 26.4 <0.001
- Midline shift 14.6 15.9 11.1 <0.001
- Non-evacuated haematoma 27.1 27.3 26.5 0.475
- Evacuated haematoma 12.7 14.4 7.9 <0.001

Outcomes:
- Mortality at 14 days 19.5 20.7 16.0 <0.001
- Death or severe disability at 6 months 37.2 36.8 38.5 0.150

*P value for comparison between low-middle income countries and high income countries.
Probabilities of mortality at 14 days (top) and death or severe disability at six months (bottom) in patient with traumatic brain injury according to income level of country. P value is for Hosmer-Lemeshow test.

Performance of models—All models showed excellent discrimination, with C statistics over 0.80 (tables 2 and 3). Calibration in all models was adequate and six out of the eight models had good calibration when evaluated with the Hosmer-Lemeshow test (figs 3 and 4).

Clinical score—Individual scores and their respective probability of outcome can be obtained from our web based calculator (www.crash2.lshtm.ac.uk/). By entering the values of the predictors, we can obtain the expected risk of death at 14 days and of death or severe disability at six months. Figure 5 shows a sample screenshot of the predictions for a 26 year old patient from a low and middle income country (Argentina), with a Glasgow coma score of 11, one pupil reactive, and absence of a major extra cranial injury. According to the basic model this patient has a probability of death at 14 days of 10% and a 23.9% risk of death or severe disability at six months. A good agreement is evident between observed and predicted outcome by the web calculator (figs 3 and 4).

External validation—Because an external cohort of patients from low-middle income countries was not available, we validated the models in patients from high income countries only. The IMPACT dataset used for the validation did not include mortality at 14 days and so we could validate only models for unfavourable outcome at six months. We validated the basic model with the variables age, Glasgow coma score, and pupil reactivity. We did not include the variable “major extracranial injury” as it was not available in the validation sample. For the CT models, we added obliteration of the third ventricle or basal cisterns, subarachnoid bleeding, midline shift, and non-evacuated haematoma to the basic model. Similarly, we excluded the variable “petechial haemorrhages” as this was not available in the validation sample.

Table 2 | Multivariable basic predictive models (excluding data from computed tomography*). Figures are odds ratios (95% confidence intervals) with z scores

<table>
<thead>
<tr>
<th>Prognostic variables</th>
<th>Mortality at 14 days</th>
<th>Death or severe disability at 6 months</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>High income countries (n=2294)</td>
<td>Low-middle income countries (n=7412)</td>
</tr>
<tr>
<td>Age†</td>
<td>1.72 (1.62 to 1.83), 14.08</td>
<td>1.47 (1.40 to 1.54), 14.10</td>
</tr>
<tr>
<td>GCS‡</td>
<td>1.24 (1.19 to 1.29), 10.22</td>
<td>1.39 (1.35 to 1.42), 25.60</td>
</tr>
<tr>
<td>Pupil reactivity:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Both</td>
<td>2.57 (1.65 to 4.00), 4.17</td>
<td>1.91 (1.53 to 2.39), 5.69</td>
</tr>
<tr>
<td>One</td>
<td>5.49 (3.70 to 8.15), 8.45</td>
<td>3.92 (3.14 to 4.90), 12.07</td>
</tr>
<tr>
<td>None</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Major extracranial injury:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>1.53 (1.11 to 2.09), 2.62</td>
<td>1.15 (0.99 to 1.34), 1.78</td>
</tr>
<tr>
<td>Yes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C statistic</td>
<td>0.86</td>
<td>0.84</td>
</tr>
</tbody>
</table>

GCS=Glasgow coma score.
*Includes age, GCS, sex, hours since injury, cause of injury, pupil reactivity, and presence of major extracranial injury.
†Per 10 year increase after 40 years.
‡Per decrease of each value of GCS.
Table 3 | Multivariable predictive models with computed tomography*. Figures are odds ratios (95% confidence intervals) with z scores

<table>
<thead>
<tr>
<th>Prognostic variables</th>
<th>Mortality at 14 days</th>
<th>Death or severe disability at 6 months</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>High income countries (n=2030)</td>
<td>Low-middle income countries (n=5635)</td>
</tr>
<tr>
<td><strong>Age†</strong></td>
<td>1.73 (1.62 to 1.84), 13.33</td>
<td>1.46 (1.39 to 1.54), 12.54</td>
</tr>
<tr>
<td><strong>GCS‡</strong></td>
<td>1.18 (1.12 to 1.23), 6.87</td>
<td>1.27 (1.24 to 1.31), 16.68</td>
</tr>
<tr>
<td>Pupil reactivity:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Both</td>
<td>2.00 (1.25 to 3.20), 2.88</td>
<td>1.45 (1.14 to 1.86), 2.97</td>
</tr>
<tr>
<td>One</td>
<td>4.00 (2.58 to 6.20), 6.21</td>
<td>3.12 (2.46 to 3.97), 9.31</td>
</tr>
<tr>
<td>None</td>
<td></td>
<td></td>
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<tr>
<td>Major extracranial injury:</td>
<td></td>
<td></td>
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<tr>
<td>No</td>
<td>1.53 (1.10 to 2.13), 2.53</td>
<td>1.08 (0.91 to 1.28), 0.89</td>
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<tr>
<td>Yes</td>
<td></td>
<td></td>
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<tr>
<td>Findings on computed tomography:</td>
<td></td>
<td></td>
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<tr>
<td>Petechial haemorrhages</td>
<td>1.15 (0.83 to 1.59), 0.84</td>
<td>1.26 (1.07 to 1.47), 2.82</td>
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<tr>
<td>Obliteration of 3rd ventricle or basal cisterns</td>
<td>4.46 (2.97 to 6.68), 7.23</td>
<td>1.99 (1.69 to 2.35), 8.25</td>
</tr>
<tr>
<td>Subarachnoid bleed</td>
<td>1.48 (1.09 to 2.02), 2.51</td>
<td>1.33 (1.14 to 1.55), 3.60</td>
</tr>
<tr>
<td>Midline shift</td>
<td>2.77 (1.82 to 4.21), 4.77</td>
<td>1.78 (1.44 to 2.21), 5.35</td>
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<tr>
<td>Non-evacuated haematoma</td>
<td>2.06 (1.49 to 2.84), 4.40</td>
<td>1.48 (1.24 to 1.76), 4.43</td>
</tr>
</tbody>
</table>

C statistic: 0.88 0.84 0.83 0.84

GCS= Glasgow coma scale.

*Includes age, GCS, pupil reactivity, presence of major extracranial injury, and all findings on computed tomography.
†Per 10 year increase after 40 years.
‡Per decrease of each value of GCS.

DISCUSSION

We have developed web based prognostic models for predicting two clinically relevant outcomes in patients with traumatic brain injury using variables that are available at the bedside. The models have excellent discrimination and good fit with both internal and external validation. We have reported on differences in outcomes and on the strength of predictors of outcomes, according to whether patients are from high or low-middle income countries.

Older age, low Glasgow coma score, absent pupil reactivity, and the presence of major extracranial injury predict poor prognosis. All of these variables have been previously identified as prognostic factors for poor outcome in traumatic brain injury. Glasgow coma score showed a clear linear relation with mortality. Our finding that mortality in patients with Glasgow coma score of 3 was lower than in patients with a score of 4 may be because scores of sedated patients are reported as 3. Increasing age was associated with worse outcomes but this association was apparent only after age 40. A similar threshold has been reported elsewhere. Plausible explanations for this include extracranial comorbidities, changes in brain plasticity, or differences in clinical management associated with increasing age. The presence of “obliteration of third ventricle or basal cisterns” on the corresponding coefficients in the validation sample. Although discrimination was, as expected, lower than in the original data, it was still quite good for both the basic and CT models (C statistic 0.77 for both models). The calibration was excellent for the CT model but poorer for the basic model (figs 6 and 7).
computed tomography was associated with the worst prognosis at 14 days. This is supported by recent findings that absence of basal cisterns is the strongest predictor of six month mortality.\textsuperscript{18} We also found—as previously reported—the independent prognostic value of traumatic subarachnoid haemorrhage.\textsuperscript{19}

Patients from low-middle income countries had worse early prognosis than those from high income countries. Regional differences in outcome after traumatic brain injury have previously been reported between Europe and North America, but the difference in mortality between low-middle and high income countries has not been explored.\textsuperscript{20}

The strength of association between some predictors and outcomes differed by region. A low Glasgow coma score had an even worse prognosis in patients from low-middle income countries compared with patients from high income countries. This might relate to quality of care or it could be that low Glasgow coma score in high income countries is associated with greater use of sedation, rather than to severity of traumatic brain injury. Increasing age had a worse prognosis in high income countries compared with low-middle income countries. This is because of even lower risks at younger ages in high income countries, while both have similar risks at older ages. Regarding computed tomography, some abnormal findings were stronger predictors in high income countries. This could be because of better technology and therefore more accurate diagnosis with computed tomography.

A systematic review identified over 100 prognostic models for patients with traumatic brain injury, but methodological quality was adequate in only a few.\textsuperscript{7} As with our models, two of the more methodologically robust models showed similarly good discrimination but worse calibration.\textsuperscript{17,21} They too included Glasgow coma score, age, pupil reactivity, and results of computed tomography as predictors, but, unlike our models, they did not include the presence of major extracranial injury, and none of them included patients from low-middle income countries.

**Strengths and weakness of the study**

Our study’s strengths are the use of a well described cohort of patients, prospective and standardised collection of data on prognostic factors, low loss to follow-up, and the use of a validated outcome measure at a fixed time after the injury. All of these factors provide reassurance about the internal validity of our models. The large sample size in relation to the number of prognostic variables examined is another particular strength. In relation to its external validity, only a few prognostic models have been developed from patients in low-middle income countries, and to the best of our knowledge the models we developed are the first with a large sample size and adequate methods.\textsuperscript{7} The external validation confirmed the discriminatory ability of the models in patients from high income countries and showed good calibration for the computed tomography model. Unlike most published prognostic models,
we included the complete spectrum of patients with traumatic brain injury, ranging from mild to severe. Finally, the data required to make predictions with the model are easily available to clinicians, and we have developed a web based risk calculator.

There are some limitations. The data from which the models were developed come from a clinical trial and this could therefore limit external validity. For example, patients were recruited within eight hours of injury and we cannot estimate the accuracy of the models for patients evaluated beyond this time. Nevertheless, the CRASH trial was a pragmatic trial that did not require any additional tests and therefore included a diversity of “real life” patients. Another limitation was that for the validation we were forced to exclude the variables major extracranial injury and petechial haemorrhages because they were not available in the IMPACT sample. Neither of these variables, however, was among the stronger predictors. The external validation showed good discriminatory ability, but this was somewhat lower than in the original data. This may be explained by a more homogeneous selected case mix in these other trials, which included only patients with moderate and severe Glasgow coma score.

Implications of the study
Most of the burden of traumatic brain injury is in low-middle income countries, where case fatality is higher and resources are limited. We found that several predictors differed in their strength of association with outcome according to income level of country, suggesting that it may be inappropriate to extrapolate from models for high income countries to poorer settings. We have developed a methodologically valid, simple, and accurate model that may help decisions about health care for individual patients. It is important to emphasise, however, that while prognostic models may complement clinical decision making they cannot and should not replace clinical judgment. This is particularly important in the context of judgments about the withdrawal of care or clinical triage. These prognostic models can also help in the design and analysis of clinical trials, through prognostic stratification, and can be used in clinical audit by allowing adjustment for case mix.22

Future research
The differences found between the prognostic models for low-middle and high income countries are important. Although most of the burden of trauma occurs in low-middle income countries, most research takes place in high income countries.3 A recent systematic review found that few prognostic models for traumatic brain injury were developed in low-middle income countries.7 More research is therefore needed to obtain reliable data from these settings. An improved understanding of the differences between these regions might also clarify the mechanisms of predictors that are not immediately obvious when we analyse a homogeneous population. Because our models were developed with data from a clinical trial, and validated only in patients from high income countries, further prospective validation in independent cohorts is needed to strengthen the generalisability of the models. Future research could also evaluate different ways, or formats, for presenting the models to physicians; their use in clinical practice; and whether ultimately they have any

**WHAT IS ALREADY KNOWN ON THIS TOPIC**

Traumatic brain injury is a leading cause of death and disability worldwide with most cases occurring in low-middle income countries

Prognostic models may improve predictions of outcome and help in clinical research

Many prognostic models have been published but methodological quality is generally poor, sample sizes small, and only a few models have included patients from low-middle income countries

**WHAT THIS STUDY ADDS**

In a basic model prognostic indicators included age, Glasgow coma scale, pupil reactivity, and the presence of major extracranial injury

In a CT model additional indicators were the presence of petechial haemorrhages, obliteration of the third ventricle or basal cisterns, subarachnoid bleeding, mid-line shift, and non-evacuated haematoma

The strength of predictors of outcomes varies according to whether patients are from high or low-middle income countries

These prognostic models, that include simple variables, are available on the internet (www.crash2.lshtm.ac.uk/)
impact on the management and outcomes of patients with traumatic brain injury.

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Argentina (359 patients): Roberto Leela, Pablo Coppari, Carolina Traverso, Alejandro Coppari (IAMBE—national and regional co-ordinators for southern Latin America); Enrique Alfredo Vergara, Carolina Montenegro, Roberto Ruiz de Hudobro, Pantaleón Saladino (Hospital San Bernardo, 106); Karina Surt, José Calizeta, Silvio Lazzeri (Hospital Escuela Jose de San Martin, 52); Gustavo Piñero, Fabiana Ciccolini (Hospital Municipal Dr Leonidas Lucero, 37); Walter Viedtta, María Fernanda Barboza (Hospital Dr Ramón Camilo, 35); Silvina Svampa, Victor Sciotto (Hospital Castro Rendon, 28); Gustavo Domenecon, Marcelo Bustamante (Hospital Zonal General De Agudos Heroes de Malvinas, 27); Maximiliano Waschbusch (Policlínico Soña T de Sanmartina, 20); María Paula Góiko (Hospital Municipal Dr Héctor D’Aguílio, 17); Daniel Alberto Drago (Hospital Nacional Profesor Alejandro Posadas, 11); Juan Carlos Arjona Linares (Hospital Español de Mendoza, 10); Luis Camputato (Hospital Italiano, 10); Gustavo Trécovii (Hospital Dr José Peraza, 5); Hernán Galimberti (Hospital Alemán, 1).
Australia (13 patients): Mandy Taitt (Gold Coast Hospital, 13).
Belgium (403 patients): Guy Mazicar (national coordinator), Véronique Oleffe, Thierry Grollinger, Philippe Delvaux, Laurent Carlier (Centre Hospitalier Regional de Namur, 356); Veronique Braet (AZ Klinika Hospital, 34); Jean-Marie Jacques (Hospital of Jolimont, 11); Danielle de Knoop (Clinique Saint-Laurent, 356); Veronique Braet (AZ Klinika Hospital, 356); Veronique Braet (AZ Klinika Hospital, 356).
Brazil (119 patients): Luiz Nasi (national coordinator), Humberto Kuokkunen, Chieko Sato (Hospital de Pronto Socorro de Porto Alegre, 11); Hiraku Kawai, Tatsuya Kiyama (University Hospital Hradec Kralove, 15); Jan Pecht (Klinika Hospital, 2).
Chile (3 patients): Pedro Bedoya Barrios (Hospital Regional de Arica, 3).
Colombia (832 patients): Wilson Guatleros, Alvaro Ardila Otero (Hospital Universitario San Jorge, 216); Álvaro Arango (national coordinator, regional co-ordinator for northern Latin America and Caribbean). Juan Ciro, Hector Jaramillo (Glúria Garcia/Clinica Las Americas, 199); Ignacio Gonzalez, Carolina Gomez (Hospital General de Medellín, 119); Arturo Arias, Marco Fonseca, Carlos Mora (Hospital Erasmo Meoz, 90); Edgar Giovanna Luna Cabrera, José Luis Betancourt, Porfiro Muñoz (Hospital Departamental de Nariño, 51); Jesus Alberto Quindiyá, Maria Esther González Castillo (Hospital San Andres, 37); Orlando Lopez (Hospital Federico Lleras, 31); Rafael Perez Yepes, Diana Leon Cuellar, Gerson Paez (Hospital El Tuná, 24); Hernán Delgado Chaves, Pablo Emilio Ordóñez (Hospital Civil de Iipiales, 21); Ricardo Plata, Martha Pineda (Hospital Universitario del Valle, 15); Libardo Enrique Pulido (Hospital Regional de Duitama, 12); John Sergio Velásquez Jaramillo (Hospital Medical Trust Kochi, 51); N K Venkataramana (national coordinator for south India); A Satish (Manipal Hospital, 50), K Bhavadasan, Raymond Morris, Ramesh S (Medical College Hospital Trivandrum, 50); A Satish (Abhya Hospital, 42);Yashbir Dewan, Yashpal Singh (Christian Medical College, 36); Rajesh Bhagdandan, Sanjana Bhagdandan (Apollo Hospital Bhopal, 32); Ajay Navale, Aniruddha (University Hospital Hradec Kralove, 15); Ranjan Shet (Klinika Hospital, 2).
India (973 patients): Yadram Yadav, Sharda Yadav, R Khatrî, Avind Baghel (NSCB Medical College, 177); Mahzar Husain (national coordinator for north India), Deepak Jha (King George Medical College, 105); Wu Hoong Chian, Mohan Dharhanda, Choon Fonying (North Bengal Neuro Research Centre, 65); S N Yang, Sanjaya Gupta (R G Medical College, 51); R R Ravi, K S Bopai, Ayaj Herur (Medical Trust Hospital Kochi, 51); N K Venkataramana (national coordinator for south India), A Satish (Manipal Hospital, 50), K Bhavadasan, Raymond Morris, Ramesh S (Medical College Hospital Trivandrum, 50); A Satish (Abhya Hospital, 42); Yashbir Dewan, Yashpal Singh (Christian Medical College, 36); Rajesh Bhagdandan, Sanjana Bhagdandan (Apollo Hospital Bhopal, 32); Ajay Navale, Aniruddha (University Hospital Hradec Kralove, 15); Ranjan Shet (Klinika Hospital, 2).
Italy (9 patients): Maria Giuseppina Annetta (Universitá Cattolica del Sacro Cuore, 4); Homére Mouchaty (Université de Firenze, 3); Eros Buzzone (Ospedale San Martino, 2).
Japan (232 patients): Beatrice Harding (CHU de Cosody, 3)); Kenya (2 patients): Mohammed Qureshi (Aga Khan Hospital, 2).
Korea (176 patients): Zanmi Lida, Jafin Abdullah NC, Ghazaime Ghazali, Abdul Rahmán Izaini Ghani (Hospital University Science Malaysia, 162); Fadzlî Cheah (Ipoh Specialist Hospital, 14).
Mexico (17 patients): Alfredo Cabrera (national coordinator), José Luis Mejía González (Hospital General Regional No 1, 12); José Luis Mejía (Hospital Pbram, 7); Filip Kramar (University Karlový Neuropsychiatric Klinik, 2).
Ecuador (258 patients): Mario Izuneta Ulloa (national coordinator), Luis Gonzalez, Alberto Daccach, Antonio Ortega, Stenio Cevallos (Hospital Luis Vernaza, 202); Boris Zurneta Cueva (Hospital de la Policia Guayaquil, 16); Marcelo Ochoa (Hospital Jose Carrasco Arteaga, 11); Jaime Valdésquez Tapia (Hospital Naval, 11); Jimmy Hurtado (Clínica Central, 8), Miguel Chong Sarmiento (Hospital Militar de Guayaquil, 11); Dr. Roberto Sotomtos (Hospital Regional del IESS "Dr Teodoro Maldonado Carbo", 5).
Greece (775 patients): Hussein Khamis (national coordinator), Abdul Hamid Abaza, Abdalla Ferky, Salah El Kordy, Tarek Shawky (Mataria Teaching Hospital, 364); Hesham El-Sayed (national coordinator), Nabil Khalil, Nader Negm, Salim Feisal (Suez Canal University, 180); Maboud Mamlam, Hany Shokry (Aswan Teaching Hospital, 160); Ahmad Yaha Elhuseney, Atf Radwan, Magdi Rashid (Zagazig University Hospital, 71).
Georgia (56 patients): Tamarr Gogaischil (national coordinator), George Ingorokoa, Nikoloz Gongadze (Neurosurgery Department of Tbilisi State Medical University, 55); Alexander Otarashvili (Tbilisi 4th Hospital, 1).
Germany (27 patients): Waltraud Klaes (Ernst Moritz Arndt University, 14); Mathias Kalkum (Kreiskrankenhaus Tirschenreuth, 8); Peter Ulrich (Klinikum Offenbach, 5).
GHANA (7 patients): Ni Andrews (Narh-Bita Hospital, 7).
Greece (20 patients): George Nakos (University Hospital of Ioannina, 8); Antonios Karavelis (University General Hospital of Larissa, 5); George Archontakis (Chania General Hospital "St George, 4"). Pavlou Mynarnthos (KAT Hospital of Athens, 3).
Indonesia (9 patients): Saturnino Lora, Saturnino Lora (Universitas Padjadjaran, 3).
Italy (9 patients): Maria Giuseppina Annetta (Universitá Cattolica del Sacro Cuore, 4); Homére Mouchaty (Université de Firenze, 3); Eros Buzzone (Ospedale San Martino, 2).
Japan (232 patients): Beatrice Harding (CHU de Cosody, 3)).

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