



Predictors of transfer to rehabilitation for trauma patients admitted to a level 1 trauma centre—A model derivation and internal validation study



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ABSTRACT

Objective: Determine the predictors of transfer to rehabilitation in a cohort of trauma patients and derive a risk score based clinical prediction tool to identify such patients during the acute phase of injury management.

Methods: Trauma registry data at a single level one trauma centre were obtained for all patients aged between 15 and 65 years admitted due to injury between 2007 and 2011. Multivariable logistic regression with stepwise selection was performed to derive a prediction model for transfer to rehabilitation. The model was tested on a validation dataset using receiver operator characteristic analyses and bootstrap cross validation on the entire dataset. A clinical prediction risk score was developed based on the final model.

Results: There were 4900 patients included in the study. Variables found to be the strongest predictors of rehabilitation after logistic regression with stepwise selection were pelvic injuries (OR 12.6 95% CI 6.2, 25.2 $p < 0.001$), need for intensive care unit admission (OR 7.2 95% CI 4.2, 12.3 $p < 0.001$) and neurosurgical operation (OR 10.5 95% CI 4.7, 23.1 $p < 0.001$). After bootstrap cross validation the mean AUC was 0.86 (95% CI 0.84, 0.89). The model had a sensitivity of 89% and specificity of 64%.

Conclusion: Intensive unit admission, neurosurgical operation, pelvic injuries and other lower limb injuries were the most important predictors of the need for rehabilitation after trauma. The prediction model has good overall sensitivity, discrimination and could be further validated for use in clinical practice.

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Introduction

Over the past two decades, the emphasis in trauma outcomes research has shifted from short term survival to long term outcomes and factors influencing quality of life after major trauma.^{1–6} Ongoing rehabilitation is an important aspect of recovery for many patients with severe injury to facilitate timely return to baseline function. The seamless transition from acute to

rehabilitation care is therefore necessary to prevent delays in access to rehabilitation therapies and long term functional recovery. In one study of hospital length of stay, one of the primary reasons for delayed discharge of trauma patients was found to be access to rehabilitation beds.⁷ Another study estimated that up to 30% of a trauma patient's length of stay consisted of “clinically inappropriate” elements such as waiting for transfer to rehabilitation beds.⁸

A number of studies have investigated clinical and non-clinical factors involved in the decision to transfer a patient to ongoing care. Factors investigated include age, ethnicity, anatomic location and severity of injury, health insurance and compensable status.^{6,9–11} One Canadian study developed a prediction model for trauma patients transferred to rehabilitation using state-wide trauma registry data. The derived multivariable model consisted of

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age, acute hospital length of stay, injury severity score, need for assisted ventilation, spinal injuries and lower limb injuries.¹² Other studies have employed multi-state and piece-wise exponential models to predict length of stay and discharge to long term care.^{13,14} These studies were designed to assist with hospital resource management and benchmarking quality of care.

The objective of the present study was to derive and internally validate a risk score based clinical prediction rule to predict the need for transfer to rehabilitation in a group of trauma patients admitted to a Major Trauma Centre. We attempted to construct the model with multi-variable logistic regression techniques using only variables that were clinically relevant and readily available to acute care clinicians. Such findings may help trauma clinicians during initial stages of injury management to identify indications for early referral and transition to in-patient rehabilitation care, particularly those with multiple injuries.

Methods

Design

This was a prediction model derivation and internal validation study.

Setting

Data was obtained from a trauma registry at an inner city Major Trauma Centre in Sydney, Australia. The trauma registry has prospectively collected clinical data on all trauma in-patient admissions since 1992. The hospital currently admits around 3000 trauma patients a year, of which around 220 patients have an Injury Severity Score (ISS) ≥ 16 . Patients were included in the trauma registry if they required trauma team activation in the emergency department or were admitted to the hospital with an injury as the primary diagnosis.

An in-patient rehabilitation service exists in the hospital on a consultative basis but all patients requiring ongoing rehabilitation were transferred to rehabilitation facilities outside this institution. These included dedicated brain injury units and orthopaedic rehabilitation facilities.

Inclusion criteria

After institutional ethics approval, the trauma registry was queried for all patients admitted between January 2007 and December 2011. Patients were excluded if they were under 15 or over 65 years of age, transferred from another facility or died within 48 h of in-patient admission. Transfers out of the hospital for burns or spinal injury management were also excluded as such patients were not routinely followed up by this trauma service.

Data collected

Variables included age, sex, mechanism of injury, diagnosed injuries, comorbidities, admission to intensive care unit (ICU), in-hospital death, length of stay and discharge destination from hospital. Operations performed during in-hospital stay were classified as neurosurgery (craniotomy, craniectomy or extracranial device insertion), laparotomy, thoracotomy, upper limb, and lower limb operations. Injuries were coded and classified using the abbreviated injury scale (AIS) and the Charlson comorbidity index (CCI)¹⁵ was used as a measure of medical comorbidities. Injuries were coded at the time of tertiary survey (within 24–48 h of admission) by a trained trauma data manager. Medical comorbidities were present if the patient had pre-injury diagnoses included in the CCI. AIS body regions classified were head, face,

neck, chest, abdomen, spinal/vertebral, upper limb and lower limb. Lower limb injuries were further classified for the purposes of this study into pelvic injuries and other lower limb injuries.

Primary outcome

The outcome of interest was discharge of the patient to a rehabilitation facility, obtained at the time of discharge from the treating medical team.

Statistical analysis

Univariate analyses using Chi-square tests for categorical data and Wilcoxon rank sum tests for non parametric continuous data were performed to compare baseline characteristics and screen for potential predictors of transfer to rehabilitation. Using statistical software (SAS version 9.3 SAS Institute, Cary, IL) the entire dataset was then randomly divided in a 1:1 ratio into derivation and validation datasets. A multivariable logistic regression model was used to develop a prediction model from the derivation dataset.

All variables were considered as *a priori* predictors except for injury severity score and length of stay. All AIS body regions were entered into the model as indicator variables, meaning a patient who has multiple body region injuries such as upper and lower limb injuries was coded “1” for upper limb and “1” for lower limb variables. The final model was selected using a stepwise selection algorithm with a variable entry and selection criteria $p < 0.05$. Receiver operator characteristic (ROC) curves were plotted and the area under the curve (AUC) was used to assess overall discrimination, the ability of the model to correctly classify a patient with or without transfer to rehabilitation. The Hosmer–Lemeshow statistic was used to test calibration, defined as how well the predicted probability correlates with the observed probability of transfer to rehabilitation across deciles of risk. All clinically relevant first order interactions were tested using interaction terms. Multicollinearity between variables, particularly between injuries and operations were tested by calculating variance inflation factors, with a threshold factor of 10 indicating potential collinearity in the model.

The model was further tested with bootstrap validation using 500 resampling simulations to obtain an estimate of mean AUC and overall optimism of the final model. Beta coefficients of model predictors were used to derive risk scores for selected variables using a previously described methodology and sensitivities and specificities calculated at relevant score cut-offs.¹⁶ The risk scores can then be added to obtain a sum total risk score, which can be used to estimate the overall probability of the primary outcome. A probability function curve were then plotted to summarise model performance as a function of possible risk scores.

Results

Study population

There were 4943 patients identified from the trauma registry of which 43 patients (0.9%) were excluded due to missing injury or discharge information.

Of the remaining 4900 patients, the mean age was 39 years (SD 14), and 67% were male. The median ISS was 4 (IQR 4.4) with 10% having an ISS greater than 15 and 8% requiring ICU admission. There were 16 deaths (0.3%) after excluding 74 early deaths within 48 h of admission. Transfer to rehabilitation occurred in 216 patients (4%).

Baseline characteristics of the derivation and validation datasets are shown in Table 1. The most common mechanism of

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