Injury, Int. J. Care Injured 47 (2016) 1879–1885

Contents lists available at ScienceDirect

Injury

journal homepage: www.elsevier.com/locate/injury

The differential mortality of Glasgow Coma Score in patients with and without head injury

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ARTICLE INFO

Article history:
Accepted 13 April 2016

Keywords:
Glasgow Coma Score
Traumatic brain injury
Mortality
Logistic

ABSTRACT

Importance: The GCS was created forty years ago as a measure of impaired consciousness following head injury and thus the association of GCS with mortality in patients with traumatic brain injury (TBI) is expected. The association of GCS with mortality in patients *without* TBI (non-TBI) has been assumed to be similar. However, if this assumption is incorrect mortality prediction models incorporating GCS as a predictor will need to be revised.
Objective: To determine if the association of GCS with mortality is influenced by the presence of TBI.
Design/setting/participants: Using the National Trauma Data Bank (2012; $N = 639{,}549$) we categorized patients as isolated TBI (12.8%), isolated non-TBI (33%), both (4.8%), or neither (49.4%) based on the presence of AIS codes of severity 3 or greater. We compared the ability GCS to discriminate survivors from non-survivors in TBI and in non-TBI patients using logistic models. We also estimated the odds ratios of death for TBI and non-TBI patients at each value of GCS using linear combinations of coefficients.
Main outcome measure: Death during hospital admission.
Results: As the sole predictor in a logistic model GCS discriminated survivors from non-survivors at an acceptable level (c-statistic = 0.76), but discriminated better in the case of TBI patients (c-statistic = 0.81) than non-TBI patients (c-statistic = 0.70). In both unadjusted and covariate adjusted models TBI patients were about twice as likely to die as non-TBI patients with the same GCS for GCS values < 8; for GCS values > 8 TBI and non-TBI patients were at similar risk of dying.
Conclusions: A depressed GCS predicts death better in TBI patients than non-TBI patients, likely because in non-TBI patients a depressed GCS may simply be the result of entirely reversible intoxication by alcohol or drugs; in TBI patients, by contrast, a depressed GCS is more ominous because it is likely due to a head injury with its attendant threat to survival. Accounting for this observation into trauma mortality datasets and models may improve the accuracy of outcome prediction.

Introduction

The Glasgow Coma Scale (GCS) was developed forty years ago to monitor the neurologic status of head injured patients [1] but was soon used to assess the neurologic status of patients with depressed consciousness of any aetiology [2]. In the United States the GCS was also adopted as a triage tool for all acutely injured patients, an extension beyond its original use to estimate prognosis

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http://dx.doi.org/10.1016/j.injury.2016.04.016
0020–1383/

only when computed after the completion of resuscitation [3]. The GCS was also incorporated into TRISS [4], an omnibus model that predicted the probability of death for any traumatically injured patient. These novel uses of the GCS had the implicit effect of expanding its use to trauma patients who did not have head injuries, an ad hoc extension of the GCS not envisioned by its creators. Nevertheless the GCS performed so well in trauma mortality models that it has been retained as an important predictor in most such models over the last 35 years (e.g. The Trauma Audit & Research Network UK [TARN] [5], Trauma Quality Improvement Programme [TQIP] [6]).

The GCS may not have been fully exploited as a predictor of mortality following injury, however. In particular, it is possible that the GCS carries different information in patients with traumatic brain injury (TBI) than patients without TBI (non-TBI), an idea that seems not to have been previously explored. We felt that a careful examination of this difference might lead to more nuanced use of the GCS in trauma models and possibly a better understanding of the GCS itself. Our findings may also have important implications for trauma benchmarking and quality improvement.

Patients and methods

Data

This study is based on data provided by the National Trauma Data Bank for 833,311 patients hospitalized in 2012. We excluded 120,688 patients under the age of 15. We also excluded 26,366 patients with one or more injuries with AIS severity of 9 because it is not possible to accurately evaluate the overall extent of anatomic injury for such patients. We further excluded 10,751 patients who were transferred to an acute care hospital rather than discharged because we could not ascertain the ultimate survival status of such patients. We excluded 23,554 patients who did not have a valid GCS score. A total of 639,549 patients remained available for analysis. We categorized these patients into one of four groups based upon AIS severity codes as follows: Traumatic Brain Injury (TBI) patients (patients having at least one AIS severity code of 3 or greater of the brain or its circulation but no other AIS severity greater than 2); patients without TBI (non-TBI) (at least one non-brain AIS severity of 3 or greater but no other AIS severity greater than 2); patients having both a brain and an non-brain injury (both); and patients having no AIS severity greater than 2 (neither). This manuscript is primarily devoted to a comparison of TBI patients ($N = 85{,}155$) with non-TBI patients ($N = 214{,}374$). While the role of GCS in predicting mortality in minimally injured patients (no AIS severity >2) is also of interest, death was too rare an event at most levels of GCS in our dataset to allow meaningful analysis of mortality in this group of patients. The University of Vermont judged this study exempt from review because it did not involve human subjects.

Statistical analysis

We compared values of covariates between TBI to non-TBI patients using the Wilcoxon rank sum test because distributions were skewed. We computed the average mortality for each group of patients (TBI, non-TBI, both, neither) at each GCS value. We also computed 95% confidence intervals for mortality in TBI and non-TBI patients at each level of GCS using the normal approximation.

We estimated a baseline logistic model in a dataset confined to TBI and non-TBI patients using GCS as the sole predictor fit as 12 indicator variables, and computed the area under the receiver operating characteristic curve (*c*-statistic) of this model to assess the overall ability of GCS to accurately distinguish survivors from non-survivors. We then re-estimated this baseline model separately for TBI and for non-TBI patients and computed the *c*-statistic for each of these models. Finally, we estimated a comprehensive model which included GCS, TBI, and their interaction as predictors, and further controlled for shock (defined as minimum systolic blood pressure less than 70 recorded in the emergency room) age, and injury severity (as tmpm, where tmpm is the logit transformation of the mortality predicted by the Trauma Mortality Prediction Model [TMPM] [7]). We computed TMPM using only AIS codes that described physical injuries, excluding physiologic measures such as level of consciousness; this required that we exclude 39 AIS codes that code for level of consciousness [range 160,202.2–1,611,000.2]). Transformations of continuous variables were selected using fractional polynomial analysis [8]. We used this comprehensive model to estimate the odds of death at each value of GCS for TBI and for non-TBI patients using linear combinations of the estimated coefficients and a four-step method described in Hosmer et al. [9] (see Statistical Appendix for details as it pertains to this model). All analysis was conducted using Stata/MP version 14.

Results

Compared to non-TBI patients, TBI patients were older and more severely injured but less often in shock. (Table 1) TBI patients had a lower median GCS score than non-TBI patients. Further, the distributions of GCS were quite different in these two groups, with GCS more evenly distributed among the 13 possible scores in TBI than non-TBI patients: only 74.0% of TBI patients had GCS scores of 3 or 15, while 92.0% of the non-TBI patients GCS scores in these two extreme categories. (Fig. 1) In all four groups of patients (TBI, non-TBI, both, neither) lower GCS values were generally associated with higher mortality. However, for both TBI and non-TBI patients GCS values of 3 were associated with slightly lower mortality than GCS values of 4. For all values of GCS the mortality of patients who had both TBI and non-TBI injuries closely tracked the mortality of patients with only TBI. (Table 2) A plot of the unadjusted mortality at each GCS value computed separately for TBI and for non-TBI patients shows that mortality is about twice as high for TBI patients compared to non-TBI patients at all GCS values less than 8; above GCS values of 8 TBI and non-TBI mortality rates are indistinguishable. (Fig. 2)

To explore the ability of GCS to discriminate between survivors and non-survivors we first estimated a baseline model with GCS as the sole predictor in dataset containing only TBI and non-TBI

Table 1
Characteristics of TBI and non-TBI patients.

	TBI	Non-TBI	*p*-Value
N	85,155 (28.4%)	214,374 (71.6)	
Died (*N*, %)	5813 (6.7%)	5713 (2.7%)	<0.001
Age (median, IRQ)	57 (36–76)	51 (30–70)	<0.001
Shock (*N*, %)	465 (0.55%)	3062 (1.43%)	<0.001
ISS (median, IRQ)	16 (9–17)	10 (9–17)	<0.001
GCS (*N*, %)			<0.001
3	5867 (6.89%)	7079 (3.3%)	
4	525 (0.62%)	248 (0.12%)	
5	586 (0.69%)	259 (0.12%)	
6	1050 (1.23%	592 (0.28%)	
7	1002 (1.18%)	578 (0.27%)	
8	888 (1.04%)	515 (0.24%)	
9	854 (1.00%)	539 (0.25)	
10	1097 (1.29)	742 (0.35%)	
11	1245 (1.46%)	873 (0.41%)	
12	1383 (1.62%)	1050 (0.49%)	
13	2683 (3.15%)	2105 (0.98%)	
14	10,798 (12.68%)	9779 (4.56%)	
15	57,177 (67.14%)	190,015 (88.64%)	