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Differential effects of the Glasgow Coma Scale Score and its Components: an analysis of 54 069 patients with traumatic brain injury.

Keywords: Components, Floor and Ceiling effects, Glasgow Coma Scale Score, GCS, Prognosis, TBI

Running title: Differential effects of the GCS Score and its components

Abstract

Introduction

The Glasgow Coma Scale (GCS) is important in the assessment of clinical severity and prediction of outcome after traumatic brain injury (TBI). The relevance of the sum score has been extensively studied, but the influence of the components seldom addressed. We aimed to investigate the contribution of the GCS components to the sum score, floor and ceiling effects of the components, and their prognostic effects.

Methods

Data on adult TBI patients were gathered from three data repositories: TARN (n=50064), VSTR (n=14062), and CRASH (n=9941). Data on initial hospital GCS-assessment and discharge mortality were extracted. A descriptive analysis was performed to identify floor and ceiling effects. The relation between GCS and outcome was studied by comparing case fatality rates (CFR) between different component-profiles adding up to identical sum scores using Chi^2-tests, and by quantifying the prognostic value of each component and sum score with Nagelkerke's R^2 derived from logistic regression analyses across TBI severities.

Results

In the range 3 to 7, the sum score is mainly determined by the motor component, as the verbal and eye components show floor effects at sum scores 7 and 8, respectively. In the range 8-12, the verbal and eye components become more relevant. The motor, eye and verbal scores reach their ceiling effects at sum 13, 14 and 15, respectively. Significant variations were exposed in CFR between different component-profiles despite identical sum scores, except in sum scores 6 and 7. Regression analysis showed that the motor score had highest R^2 values in severe TBI patients, whereas the other components were more relevant at higher sum scores. The prognostic value of the three components combined was consistently higher than that of the sum score alone.

Conclusion

The GCS-components contribute differentially across the spectrum of consciousness to the sum score, each having floor and ceiling effects. The specific component-profile is related to outcome and the three components combined contain higher prognostic value than the sum score across different TBI severities. We, therefore, recommend a multidimensional use of the three-component GCS both in clinical practice, and in prognostic studies.

Introduction

The Glasgow Coma Scale (GCS) has been widely adopted both in clinical practice and health care research as an instrument for assessing the (depressed) level of consciousness[1]. GCS assessment involves recording responsiveness in three domains: the eye opening, motor and verbal responses to speech and (if not responding) to a stimulus. Formal clinimetric analysis of the GCS was not performed upon its introduction in 1974. Later studies reported floor and ceiling effects of the components, but these have never been definitively established in large patient numbers [2,3]. Soon after the introduction of the GCS, a numerical score was assigned for each of these responses allowing for import of clinical data into a data bank[4]. The component scores (shaping the GCS scale) should be differentiated from the derived sum score, i.e. the summation of the numeric values of the three components. The sum score was initially used in research settings only, but is increasingly used in clinical practice as a replacement for the description of the three responses. Application of the sum score as a classification system to define clinical severity of patients with traumatic brain injury (TBI) is widely adopted, distinguishing mild (sum score 13-15), moderate (sum score 9-12) and severe (sum score $\leq$ 8) TBI. Over time, the sum score was moreover included in various clinical stratification and outcome prediction scores, such as Acute Physiology and Chronic Health Evaluation (APACHE) II [5], Revised Trauma Score (RTS) [6], Trauma and Injury Severity Score (TRISS) [7], and adopted in several guidelines such as the National Trauma Triage Protocol [8] and severe TBI guidelines [9]. Summing of the components, however, brings along consequences not foreseen at the time its introduction, including loss of information on the scores of the individual components and uncertainty about how to deal with untestable components. The information comprised by the sum of the three components might be less than that contained in the components separately [10–12]. Teasdale et al. advocate in a more recent report to use the scale in the management of individual patients, and to restrict use of the sum score for summarizing information on groups of patients [1].

The prognostic value of the sum score has been extensively studied in patients with TBI. The sum score appeared to relate to various outcome measures, including case fatality rate, the Glasgow Outcome Scale (GOS), the Disability Rating Scale (DRS) and the Rancho Los Amigos Levels of Cognitive Function Scale (LCFS) (modest correlation only) [13]. Lower sum scores have been shown to be associated with poorer outcome, and an inverse, approximately linear relation between mortality and sum score is reported in patients with TBI [1]. However, fatality rates may differ for patients with different combinations of the three component scores despite similar sum scores [14–16]. This raises questions about the relative contribution of the GCS components to the sum score, how these contributions may change across the broad spectrum of severity (i.e. sum score 3 to 15), and differentially influence the relation of the sum score with outcome.

This study aimed to explore how the GCS components contribute to the sum score across injury severity levels, to identify floor and ceiling effects of the components, to investigate how the component-profile might affect the association of sum scores with outcome and to investigate the relation of each component and sum score with outcome across different TBI severity levels.

Methods

We performed a retrospective observational study. The STROBE statement was used to guide the reporting of this study [17].

Patient population and Datasets

Data on patients with TBI were accessed from two trauma registries: Trauma Audit and Research Network (TARN) and Victorian State Trauma Registry (VSTR); and one randomized clinical trial with very broad inclusion criteria, which as such can be considered a 'large pragmatic trial': Corticosteroid Randomization After Significant Head Injury (CRASH) (see Table 1). Consent procedures and IRB approvals are described for the studies separately.

Trauma Audit and Research Network (TARN): TARN is a hospital-based trauma registry in England and Wales that includes patients with trauma resulting in immediate admission to hospital for more than 3 days, critical care admission and/or transfers for critical care, or death after admission. The injuries of each trauma case are coded using the abbreviated injury scale (AIS) dictionary [18]. The central TARN database retains no patient identifiers. Approval for research on this anonymised data set has been issued by the UK Health Research Authority (PIAG sections 251) [19]. For the current study, we selected patients of > 15 years of age enrolled between 1988 and 2014 with TBI, defined as having any AIS-head score, resulting in a dataset of 50064 patients. The outcome measure is survival to discharge or 30 days post injury (whichever is earliest), which was available in 100%.

Victorian State Trauma Registry (VSTR): The VSTR, established in 2001, is a statewide trauma registry, which captures information about all major trauma patients from 138 health services in the state of Victoria in Australia, whose principal diagnosis is injury, irrespective of age. Major trauma, as defined by the VSTR, includes death, admission to an intensive care unit, an injury severity score (ISS) >15, and urgent surgery (within 24 hours of admission and surgery involving intracranial, intrathoracic, intra-abdominal injury or fixation of spinal or pelvic fractures) [20]. The VSTR records patient and injury details as well as information about outcomes. Diagnoses are coded according to the AIS 2008, and the ISS is calculated to provide an overall rating of the severity of the patient's injuries. Outcome assessment includes mortality at discharge and the Glasgow Coma Scale Extended (GOSE) at six months, derived via telephone interview. The VSTR uses an opt-out consent process, where all eligible patients are provided with a letter and brochure explaining the purpose of the registry, the data collected, and what the data are used for, but also how to have their data removed from the registry if they wish to. The opt-off rates are less than 1.0 % [21]. Data of patients of over 15 years of age, presenting with any AIS head code, except for minor superficial injuries, that occurred between July 2001 and July 2013 was extracted, resulting in 14062 cases. AIS-Head severity score was ≥ 3 in 77%. Mortality at discharge was available in 14062 patients (100%).

Corticosteroid Randomization After Significant Head Injury (CRASH): CRASH was a randomized controlled trial with broad inclusion criteria studying the effect of corticosteroids on death and disability after TBI. CRASH was conducted in both high- and low/middle-income countries. The multicentre research ethics committee gave approval for the trial to be conducted using a "consent waiver" [22]. CRASH enrolled 10 008 patients suffering TBI with a GCS score of 14 or less, within 8hours of injury between 1999 and 2005. Outcome at six months was assessed by a simple postal questionnaire version of the GOS and also 14-day mortality was collected. A total of 9941 patients were ≥ 16 years old and were selected for inclusion in this study. Fourteen-day mortality was available in 99% of patients.

Characteristics of these datasets are summarized in Table 1. The data sources were chosen based on the availability of patients having a broad spectrum of TBI severities (good spread of GCS scores) in adult patients alongside well-characterized injury descriptions and outcomes. The outcome examined in this analysis is mortality at discharge, as this time point was consistently present across the data sets. In CRASH, we considered 14-day mortality a suitable approximation for discharge mortality, as in a previous study it was shown that the median length of stay was 11 days (IQR: 5-27) [23]. The inclusion of three different databases contributes to broad applicability by including a wide range of patients and permits exploration of contextual factors, including different clinical settings and geographic influences.

Statistical methods

Analysis of the contribution of the GCS components to the sum score

Patients with both GCS component scores and sum score obtained after arrival in hospital were used for analyses. Analyses included descriptive analysis of the components of the GCS and its sum score and their interrelations. The relation between the median GCS component score and the sum score is presented graphically. The different component profiles adding up to identical sum scores were explored and displayed graphically. Results were explored in each data set separately and in the merged datasets.

Analysis of associations of the GCS and sum score with outcome

a. Analysis of case fatality rates in subgroups with varying GCS component-compositions

We compared the case fatality rates (CFR) among patients with different GCS components-profiles adding up to identical sum scores by using the Chi squared test. For this analysis we selected only the components-profile groups for which at least five deaths could be expected by taking into account the overall mortality for all patients with an identical sum score. Patients with known GCS component scores, sum score and outcome, were included for this analysis. We examined data from each database separately followed by a combined analysis.

b. Prognostic value of the GCS differentiated by TBI severity level

The relations between the CFR and the GCS components and sum score, respectively, were explored using univariate logistic regression models. We tested for non-linear relations by adding a quadratic term to the regression model (polynomial regression). From these regression models, the Nagelkerke's R^2 [24] was derived to quantify the prognostic value of GCS components and the sum score. Nagelkerke's R^2 can be interpreted as an approximation of the percentage variability in outcome that is explained by the GCS components [25]. To examine whether one of the GCS components alone added predictive value above that of the other two components (or in other words: to correct for correlation between the components), we plotted differences in Nagelkerke's R^2 values of the model including all three components, when the one component was included and excluded from the model. These partial R^2 values reflect the 'added prognostic value', or the 'uncorrelated prognostic value' of a component. Moreover, the prognostic values (R^2) of both the combination of the three components (EMV) and of the sum score were analysed, and the goodness of fit (LR chi2) of both models were compared using the chi2-test. To control for TBI severity, the analyses were performed both in subpopulations according to TBI severity based on the GCS, and in all patients. Results are plotted in bar plots, with the open bars presenting the unadjusted R^2 and the hatched bars presenting the partial (uncorrelated) R^2 values for the components. The results are differentiated by data source.

Data analysis was conducted using R software for statistical computing and graphics (version 3.1.3) (R Foundation for Statistical Computation, Vienna, Austria).

Results

A total of 74067 adult patients with TBI (CRASH n=9941; TARN n=50064; VSTR n=14062) were included. The sum score was reported in 65568 (89%) patients, but the frequency of specific sum scores varied between datasets, reflecting different populations (Fig. 1). The eye, motor and verbal scores were each reported in 73% of patients. Of the total patient population, 54069 (73%) patients had complete data on both the eye, motor, verbal (EMV) profile and the sum score. Of these 54069 patients, 54040 (99.9%) patients had available data on discharge mortality.

Contribution of the GCS components to the sum score: floor and ceiling effects

The composition of the sum score upon admission was analysed in the individual data sets and in the combined data sets of 54069 cases in which both the GCS and sum score data were present. Fig. 2 presents the graphical composition of the mean GCS component score across the entire spectrum of severity (sum score 3-15). Results as shown were consistent across the individual data sets.

In the sum score range 3 to 7, a steady increase in the mean motor score is observed (from 1 to 5 on the six category score), whereas the eye and verbal scores remain low. Consequently, in the majority of patients with sum scores ranging from 3 to 7, the sum score reflects changes in the motor response only.

The motor component shows a plateau phase from sum scores 7 through 12. In this range, the sum score is mainly influenced by both the verbal and eye components. From sum score 12 to 13, the motor score again influences the sum score and accordingly reaches its ceiling effect at sum score 13. The floor and ceiling effects of the eye response are reached at sum score 8 and 14, respectively. The floor and ceiling effects of the verbal response are found at sum score 7 and 15.

When the three components are evaluated separately, mathematically a total of 120 possible combinations of the three components can occur, as the sum scores 4 to 14 can be made up of different GCS component-profiles. Although, some profiles are clinically not feasible, we identified all 120 different combinations in the data sets. However, some profiles were much more prevalent than others (see Fig. 3).

Analysis of associations of the GCS and sum score with outcome

a. Analysis of case fatality rates in patients with varying GCS component-compositions

We investigated whether significant variations in CFR were present between different component-profiles with identical sum scores (Fig. 3). Considering all data together (N=54040), significant differences in CFR were found between different component-profiles of all identical sum scores ranging from 4 to 14 ($p<0.01$), except for sum scores 6 ($p=0.48$) and 7 ($p=0.07$) (Table 2). Across the three datasets, results showed similar trends, although significant different fatality rates were confirmed for fewer sum scores due to smaller numbers in the separate datasets.

b. Prognostic value of the GCS differentiated by TBI severity level

We examined the prognostic value of each GCS component and the sum score and how these relations might change across different levels of TBI severity: mild: sum 13-15, moderate: sum 9-12, severe sum 3-8. Univariate logistic regression analyses identified decreasing case fatality rates with increasing scores of either the components or sum score in all data sets.

Fig. 4 shows the relative prognostic value of the components and sum score expressed as Nagelkerke's R^2 values for each data set. In CRASH and TARN we identified increasing R^2 values with increasing TBI severity. In mild and moderate TBI the prognostic values of all components were lower. In VSTR, however, R^2 values did not increase much in patients with severe TBI. An exploratory analysis in VSTR, in which we excluded TBI patients who suffered from extra cranial injuries (i.e. selecting isolated TBI patients (n=2967)), showed clearly higher R^2 values: not only in patients with severe TBI, but also across all severities.

In all data sets, the motor score had the highest prognostic value (partial R^2) in patients with severe TBI compared to the other components. However, in patients with less severe TBI its prognostic effect was lower. Both the eye and verbal components held prognostic value at different TBI severity levels, but prognostic effects differed between data sets. In every data set, the verbal component showed highest R^2 of all components among patients with mild TBI.

The prognostic value of the three components combined (E+M+V) in the logistic regression models was consistently higher than the R^2 of the sum score across different severities. This can be related to the observation that different EMV-compositions with identical sum scores carry a different mortality risk. In all data sets and across all TBI severities, the goodness of fit (LR chi2) was significantly higher for the E+M+V-model compared to the model including the sum score only ($p<0.001$). Only in patients with severe TBI derived from VSTR database, the sum score model and E+M+V-model had a similar goodness of fit ($p=0.13$).

Discussion

This pooled analysis of individual patient data in 54069 patients with TBI has shown how the three components of the GCS contribute to form the sum score at different levels of depressed consciousness. We identified clear floor and ceiling effects. Moreover, the specific combinations of components imply different clinical situations of patients and we demonstrated a significant impact on the relation with outcome. These results underline the relevance of reporting each GCS component over the sum score, both in individual clinical data as well as in prognostic models.

Floor and ceiling effects of the GCS components

The three behavioral responses making up the GCS show a specific interaction early after head injury across the full spectrum of consciousness (Fig. 2), and patterns appeared similar across the different included data sets, despite differences in case mix. This descriptive analysis of the component variables of the scale, results in better understanding of the clinimetric aspects of the GCS. In patients having sum scores ranging from 13 to 15, reflecting mild TBI, the motor score is not influencing the level of consciousness at all, as it reaches its maximum influence (ceiling effect) at sum score 13. Of the patients having a sum score of 14, 73% showed impairment in the verbal response (V4) as the eye response reached its ceiling effect at sum score 14. Clinically this demonstrates that the majority of patients will be disoriented as a first sign of reduced consciousness. In the patients with sum scores ranging from 8 to 12, first the verbal response (sum score 8), next the eye (sum scores 9-10) and then again the verbal response (sum scores 11-12) will contribute to an increasing sum score. At these levels of consciousness (sum score 8-12), the majority of patients are localizing to painful stimuli (M5) and they show no alteration in their motor response (plateau phase). In the patients with severely depressed consciousness (sum scores 3-7), the level of consciousness is mostly influenced by the motor response only until it reaches a plateau phase at sum score 7, as the floor-effects of both the verbal and eye response occur at sum score 7 and 8, respectively. Based on this specific interaction pattern, the current definition of severe TBI (sum 3-8) may be challenged. As there is a clear flattening of the influence of the motor score at the plateau phase occurring at sum score 7, the range 3-7 might be more appropriate. Already in 2002, Jennett recognized that according to the original definition of severe TBI as introduced by Jennett et al. in 1977, all patients with a sum score of 7 were in coma, but only half of those with sum score 8 [26]. However, the current '3-8' definition for severe TBI is so deeply embedded in clinical practice and research, that we do not consider this difference large enough to warrant any change in current practice.

The interaction pattern as revealed in the current study relates only partially to those presented by Bhatty et al. 1993 [2], who studied the mathematical foundation of the GCS. They concluded that the motor component of the GCS was dominant at the lower end of the sum score, the verbal component dominated between sum scores 8 and 10, and the eye component at the higher end. Results shown in their study are, however, based on an unknown number of cases and only 15 most relevant GCS component-profiles were selected for analysis. Peters 2010 published the relative distribution of each component within the modified GCS sum score and showed how in the range of 3 to 8 the eye and verbal scales are typically at minimum values. In children admitted to the intensive care unit, often having a sum score of 8 or less, the motor score alone would therefore be anticipated to distinguish between poor and good outcome [3]. Other studies have suggested that the eye and verbal components can be omitted without compromising the predictive accuracy of the GCS as the motor score accounts for almost all the predictive power, both in adults as in children[14,27–33]. However, the current study illustrates how different levels of the sum score are influenced by each component of the scale. It shows how the relative contribution of the motor score diminishes after it reaches a plateau phase at sum score 7 and how the verbal and eye components have increasing relevance in patients with less depressed levels of consciousness. The influence of each component is also reflected in their prognostic values across the spectrum of severity as shown in Figure 4. From this perspective, the motor-score only approach could be justified in patients with severe TBI only, as was also suggested by Teasdale et al. in 1979 [12]. The floor and ceiling effects are also relevant with regard to clinical decision-making, as from our experience clinical decisions to undertake surgery are often based on a decline in the motor score. This can be a misleading approach at the higher levels of consciousness (i.e. in patients localizing to pain and obeying commands), considering clinical evolution and outcome in these patients will mainly depend on changes in the eye and verbal responses. In conclusion, the complex interaction pattern of the three components across the full spectrum of consciousness necessitates a multidimensional approach to adequate assessment as carried out by testing the three components of the scale.

GCS-component-profiles and prognosis

The sum score comprises various clinical situations, reflected by different combinations of the GCS components. Principal component analysis has previously shown that summation of the three components implies a substantial loss of clinical information [10].

In this study all 120 possible GCS-component-profiles that are comprised in the 13 different sum scores were identified. However, some of these are unlikely from a clinical perspective (f.e. no eye opening, abnormal flexion to stimuli but normal verbal response, E1M3V5). These clinically improbable combinations were not frequently encountered and presumably reflect errors in data entry.

The specific composition of components adding up to a certain sum score is relevant to outcome as revealed by this study. Significantly different outcomes were identified among different GCS-component-profiles with identical sum scores. This was demonstrated for every sum score ranging from 4 to 14 ($p<0.01$), except for sum scores 6 and 7. Similar findings have been reported in other studies: In 1979 Teasdale et al. showed that in patients with severe TBI (sum score 8), outcome was similar despite different component profiles[12]. Healey et al. included large patient numbers reflecting a general trauma population, and confirmed significant differences in hospital discharge survival rates except in patients with sum scores 6, 12 and 13[14]. Hirai et al. observed differences in 6-months GOS in patients with a sum score of 14 that underwent surgery for cerebral aneurysm rupture [15]. And Teoh et al. included 1390 patients admitted to a general intensive care unit and found significant different mortalities during ICU admission in patients with component-profiles adding up to sum scores 7, 9, 11 and 14 [16]. Although these varying results are presumably related to differences in patient population and outcome measures, they underline the relevance of reporting and incorporating the three components rather than the sum score alone. The sum score does not equal the sum of the GCS-components.

The GCS, sum score and prognosis

This study reveals how the three components hold varying degrees of prognostic value (partial R^2) across different TBI severity levels. The prognostic values of the components may be related to their floor and ceiling effects across the spectrum of consciousness as demonstrated in figure 2. The higher prognostic value of the motor score in severe TBI patients diminishes at higher sum scores, whereas the eye and verbal scores have relative higher R^2 values in less severe TBI patients. Nevertheless, R^2 values were relatively low for all three components in patients with mild TBI, reflecting overall low mortality in this population group and as such a limited value of the GCS in terms of predicting mortality. The results of the regression analyses showed, moreover, that reporting the sum score only, implies a loss in prognostic information. The prognostic value of the three components combined (E+M+V) was higher (R^2 = 21.1%, 21.6% and 26.8% in TARN, VSTR and CRASH) than the R^2 of the sum score (R^2 = 20.2%, 20.5% and 26.3%, respectively). This finding was consistent across TBI severity levels.

Various other studies have explored the importance of the GCS components versus the sum score in outcome prediction and reported conflicting results. Teasdale et al. reported the average reduction in entropy or uncertainty as presented by the information influence coefficient, which is a measure of the amount of information that is lost when using the sum score instead of the three components for predicting outcome. The sum score performed less compared to the three components combined and they concluded that it is of importance to convey maximum information by considering each component separately[12]. Healey et al., using fractional polynomial models, showed that the eye score did not add predictive value, and, although the verbal score did add little predictive value, advocated a motor-score only approach[14]. Gill et al. used the area under receiver operating characteristic curves (AUC) to calculate the predictive ability of the emergency department GCS and showed that the components alone as well as two simplified 3-point scores showed similar test performances compared to the sum score for prediction[34]. Moore et al. showed good discrimination for the sum score, whereas the eye component did not add predictive value to the combination of the motor and verbal component. Using the three components separately, rather than the sum, did not improve the predictive model. They concluded that there is no need to use each component separately, and instead only the sum score is needed to accurately predict mortality[35]. Lesko et al. explored the prognostic value of the GCS by logistic regression models deriving the AUC, the classifications accuracy and Nagelkerke R^2 from each model. They found that the sum score had similar prognostic value as the motor or the verbal score, or any combinations of the three components. They, however, do not support omission of the eye and verbal scores in clinical practice, as they recognize the added value of these scores in more moderate degrees of injury[30].

The available evidence base prevents drawing clear conclusions regarding the predictive ability of the three components and the sum score. A likely explanation for the conflicting results can be found in an interaction with the type of patient population, the TBI severity, the type of outcome measure, and the time of GCS and outcome assessment. In the current study, the associations of the GCS with early mortality in the patients with severe TBI were less pronounced in VSTR compared to the other data sources. We hypothesized that the presence of major extra-cranial injuries in this patient population had an influence on the relation with outcome, irrespective of the neurologic condition. Indeed, the R^2 values increased in the isolated TBI population, mainly in the patients with severe TBI. In a previous study capturing data from 'International Mission on Prognosis and Clinical Trial Design in TBI' (IMPACT), TARN and CRASH, the effect of major extra-cranial injuries was found to be an important prognostic factor in TBI patients, although the effect varied by population[36]. Osler et al. recently suggested in this journal that the sum score is a stronger predictor in trauma for patients with TBI compared to those without TBI[37]. This again accentuates limitations of the sum score in prognostication with a potential differentiating effect for the presence of TBI. The conflicting findings in the literature, as well as the varying results in the different data sets as presented in this study underline the relevance of incorporating the three components separately and the need for multidimensional approaches to prognostication. Moreover, they illustrate that incorporation of the sum score in trauma triage protocols and general scoring systems may be relatively crude and carries limitations.

Strengths and limitations of this study

We performed a detailed analysis of the GCS and its effect on case fatality from three different data sources with a total of 54069 cases, thereby accounting for differences in patient populations, and inclusion criteria. Various limitations should, however, be acknowledged. First, we excluded cases in which data points were missing, and only performed complete case analysis. We anticipated this not to be a potential selection bias, as we considered it likely that the missing values were randomly missing due to logistical reasons. Also, imputation of missing data was not considered of added value, since the sum of imputed component scores would not strictly match the actual sum score. Moreover, as we studied a considerable amount of data, deriving satisfying error estimates was not considered problematic. Second, the outcome measure used in this data analyses was restricted to early mortality, reflecting the confined content of the main data source employed (see table 1). Third, we did not adjust for other possible prognostic factors in the prognostic analysis as the primary interest of these analyses was in the GCS: we aimed to compare the different components of the GCS in terms of the variance in outcome they explain. Also, we recognize that case fatality rate in patients with sum score 15 is rather high (10%). This finding is driven by the results of the largest dataset in this study, which included patients with systemic injuries in addition to TBI. Finally, we recognize that the actual R^2 values as presented in this study are relatively low, suggesting that the components, taken in isolation, will predict poorly. This emphasizes that outcome prediction in TBI necessities a multidimensional approach[38].

Conclusions and clinical relevance of this study

This research shows how the eye, motor and verbal components, each carrying unique clinical information, have floor and ceiling effects in their contribution to form the sum score across different levels of consciousness. The specific sequence of scoring of the components is, moreover, essential with regard to clinical practice and in determining the short-term outcome in patients with head injury. Finally, the three components combined show consistently higher prognostic value compared to the sum score across different severity levels. Consequently, summing the GCS does not equal the sum of its parts, but rather implies a considerable loss of information. Moreover, the relation of the GCS with outcome seems context dependent. We, therefore, endorse a multidimensional use of the three-component Glasgow Coma Scale, both in clinical practice for assessing and follow up of patients with acute TBI and in general trauma stratification and prognostic models.

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