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RESEARCH ARTICLE

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The GCS-Pupils (GCS-P) score to assess outcomes after traumatic brain injury: a retrospective study

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ABSTRACT

Introduction: The Glasgow Coma Scale (GCS) and pupil response to light are commonly used to assess brain injury severity and predict outcomes. The aim of this study was to investigate whether the GCS combined with pupil response (GCS-P), compared to the GCS alone, could be a better predictor of hospital mortality for patients with traumatic brain injury (TBI).

Methods: A retrospective cohort study was undertaken at an adult level one trauma centre including patients with isolated TBI of Abbreviated Injury Scale above three. The GCS and pupil response were combined to an arithmetic score (GCS score (range 3–15) minus the number of nonreacting pupils (0, 1, or 2)), or by treating each factor as separate categorical variables. The association of in-hospital mortality with GCS-P as a categorical variable was evaluated using Nagelkerke's R^2 and compared using areas under the receiver operating characteristic (AUROC) curve.

Results: There were 392 patients included over the study period of 1 July 2014 and 30 September 2017, with an overall mortality rate of 15.2%. Mortality was highest at GCS-P of 1 (79%), with lowest mortality at a GCS-P 15 (1.6%). Nagelkerke's R^2 was 0.427 for GCS alone and 0.486 for GCS-P. The AUROC for GCS-P to predict mortality was 0.87 (95%CI: 0.82–0.72), higher than for GCS alone (0.85; 95%CI: 0.80–0.90; $p < .001$).

Discussion: GCS-P provided a better predictor of mortality compared to the GCS. As both the GCS and pupillary response are routinely recorded on all patients, combination of these pieces of information into a single score can further simplify assessment of patients with TBI, with some improvement in performance.

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Wounds and injuries; brain injury; Glasgow Coma Scale; pupil constriction; mortality

Introduction

Traumatic brain injuries (TBIs) are a major source of death and disability globally, despite advancements in prevention, treatment and management in emergency and trauma care.[1] Within the population of patients experiencing TBI, initial presentations can range from 'mild' to 'severe' with recovery levels correlated with initial presenting clinical findings and varying depending on the severity of the injury from good outcomes and resumption of premorbid lifestyles to profound disability or death.[2]

A number of neurological screening tools have been used to measure a patient's level of consciousness and neurological function after head injury.[3] The most common tool to measure the severity of TBI is the Glasgow Coma Scale (GCS) which provides an indication of the patient's level of consciousness.[4] The GCS severity is determined by the patients' response to three neurological measures of motor, verbal and eye function.[4] Another commonly used tool in clinical practice is the pupil size and response, which is measured in millimeters (mm) through the use of a standardized pupil scoring system.[5] The pupils should be both equal and reacting to light (PEARL) by shining a pen torch/light in the patient's eyes or by using a pupillometer.[5,6]

In 2018, Brennan et al. investigated how the GCS combined with pupil response (GCS-P), a combination of the GCS and pupil response measure, predicted patient mortality and neurological outcomes.[7] They developed a method to combine both the GCS score and pupil response as a clinical indicator into a single index. Pupils that were both equal and reactive to light scored a two, pupils that were reactive to light in one eye only scored a one, and when both pupils were not reactive to light a score of zero was applied.[7] The study then combined the GCS scores and pupil scores into a newly formed GCS-P score that ranges from 1 to 15. GCS-P correctly predicted 74% deaths compared to a prediction of 51% of deaths when using the GCS only. It was proposed that the GCS-P model had the potential to have a higher sensitivity to neurological severity due to a wider range of variables that were incorporated into the score.

However, smaller studies have not demonstrated better sensitivity,[8] and the GCS-P is not routinely used in clinical practice. The aim of this study was to evaluate the performance of GCS-P for predicting outcomes in a cohort of patients with TBI presenting to an adult major trauma centre in Australia.

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Materials and methods

Design

This was a retrospective cohort study.

Setting

The Alfred Hospital is the busiest adult trauma service in Australia and admits over 1600 major trauma patients per year. Within the Victorian State Trauma Service, it is one of the two adult major trauma services which provide adult major trauma services to a state-wide population of about 6.3 million people.

All major trauma presentations that presented directly from the scene to The Alfred between the 1 July 2014 and 30 September 2017 were eligible for inclusion in this study. The inclusion criteria for The Alfred Trauma Registry have been previously described and include patients with an Injury Severity Score (ISS) of >12, death after injury, admission to ICU for more than 24 hours with mechanical ventilation, partial and full thickness burns ≥20% total body surface area, urgent surgery within 48 hours from arrival such as craniotomy, thoracotomy, laparotomy, pelvic or spine surgery or interventional radiology.[9]

Inclusion criteria

Included in this study were patients who had an isolated TBI with an Abbreviated Injury Scale (AIS) of the head of ≥3 and injury score to other body regions ≤2. We selected the population with isolated TBI as this is the population where the GCS-P is likely to have the greatest benefit in predicting outcomes. It was assumed that among patients without brain injury, the pupillary reaction, even if abnormal, would not be associated with mortality. In addition, data for both GCS and pupil scores on presentation had to be available and all included patients were aged over 18 years.

Data extracted

The primary outcome variable was mortality at hospital discharge. The first recorded GCS after injury was extracted. For patients who were sedated or intubated prior to hospital arrival, the pre-hospital GCS recorded prior to intubation was used. The pupil response on arrival were sub-grouped to three categories: If both pupils were unreactive to light the score was 2, if only one pupil was unreactive to light the score was 1. If both pupils were reactive to light, the score was 0.

Statistical analysis

To calculate the GCS-P score, the pupil score was subtracted from the GCS score. Scores on the GCS-P could therefore range from a minimum of 1 to maximum of 15. Logistic regression was used to model death at hospital discharge. Consistent with the methodology used when developing the GCS-P score and clinical utility, we treated GCS-P as a categorical variable.

The proportion of variability in outcome explained by the model was assessed using Nagelkerke's R^2. Nagelkerke's R^2 is a measure of the proportion of variability in outcome that is explained by the logistic regression model, with a value of ≤0.2 indicating a weak association, 0.2–0.39 indicating a moderate association and values ≥0.4 indicating strong association. Furthermore, we explored the predictive ability of GCS-P for death at hospital discharge using area under the receiver operating characteristic (AUROC) curve and compared this with the AUROC using the GCS alone. To compare AUROCs, a test for the equality of the area under the curves was performed, using an algorithm suggested by DeLong et al.[10] As the GCS-P is expected to be of greater value among patients with severe injury, we also undertook a sub-group analysis of patients who presented with an initial GCS <9. All analyses were conducted using Stata v 15.1 (College Station, TX). A p value of <.05 was considered to be statistically significant.

Ethical approval

Ethical approval for this study to take place was received from the Alfred Health Human Research Ethics Committee (HREC) (139/19) and the La Trobe University Ethical Committee (based on external approval) (439/19).

Results

There were 400 patients available for inclusion during the study period of which data on pupillary response were available on 390 patients. Demographic and outcome data are presented in Table 1. There were no deaths among patients with ISS < 13. These patients met the inclusion criteria for mechanical ventilation or burns. The median length of stay in hospital was 102 hours (IQR: 57–219). Among patients that died, median length of stay was 58 h (IQR: 21–152).

Most patients were male, presented with a GCS 13–15 and had pupils that were equal and reactive to light. Figure 1 displays the proportions of death at hospital discharge. Among patients with GCS-P of 1, the proportion of patients that died was 79% and among patients with GCS-P of 15, the proportion was 1.6%.

Treating GCS alone as a categorical variable had a Nagelkerke's R^2 of 0.427. Treating GCS-P as a categorical variable had a Nagelkerke's R^2 of 0.486. The AUROC for GCS-P to predict mortality was 0.87 (95%CI: 0.82–0.72), which was significantly higher than the AUROC for GCS alone (0.85; 95%CI: 0.80–0.90; $p < .001$) (Figure 2). Among patients with an initial GCS < 9, for the outcome of death in hospital, the GCS-P has

Table 1. Patient characteristics.

Variable	Summary measure
Age (years; mean (SD))	56.0 (24.2)
Sex	
Male	268 (68.7%)
Female	122 (31.3%)
GCS score	
13–15	263 (67.4%)
9–12	36 (9.2%)
3–8	91 (23.3%)
Pupil response	
Equal and reactive to light	355 (91.0%)
Fixed dilation of one pupil	16 (4.1%)
Bilateral fixed dilation of pupils	19 (4.9%)
ISS	
<13	175 (44.9%)
13–25	165 (42.3%)
>25	50 (12.8%)
Head max AIS	
3	178 (45.6%)
4	110 (28.2%)
5	102 (26.1%)
Mortality	59 (15.1%)

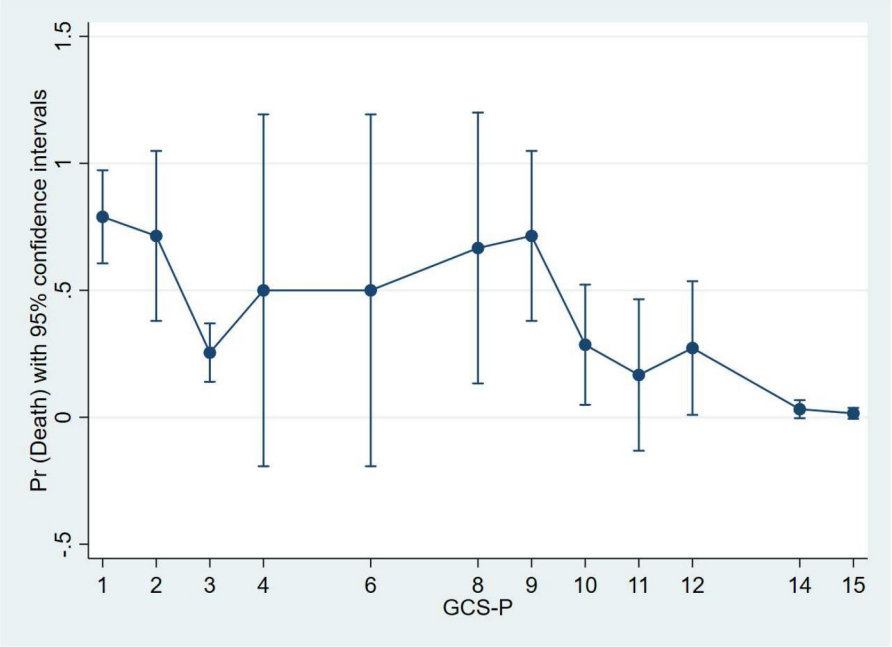

Figure 1. Proportions of death among categories of GCS-P.

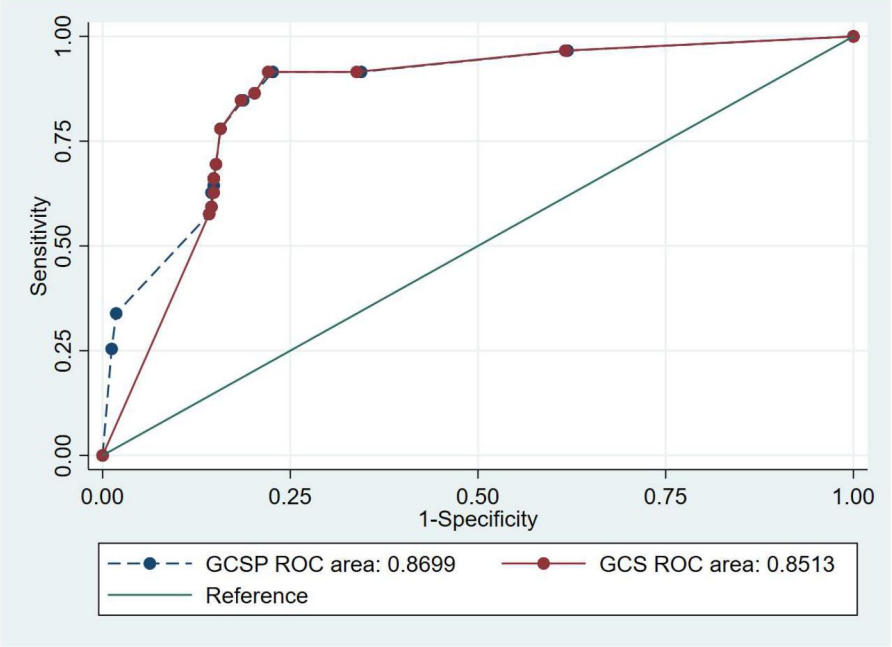

Figure 2. AUROC for GCS-P and GCS.

an AUROC of 0.63 (95%CI: 0.51–0.74), compared to the AUROC of GCS alone of 0.44; 95%CI: 0.38–0.51, $p < .001$.

Discussion

The combination of pupil scores and GCS, i.e. GCS-P, provided better discrimination for death at hospital discharge. This supports the use of the GCS-P as a single metrics during assessment of patients with TBI. The benefits appeared more profound among patients who presented with a low GCS.

Previous studies had indicated that the GCS-P was a more effective predictor of a patients prognosis than GCS alone.[7] It was noted that the GCS-P model may be useful platform about key prognostic features which can be added in a simple format useful in clinical practice.[3] The challenges with prognostic models being translated into clinical settings are that the models themselves are being practical to use for health practitioners. Thus, prognostic models should be implemented in a way where they are user-friendly to promote the use of prognostic models in the clinical setting as it appears to be more clinical effective but accessible for clinicians. The GCS-P meets these criteria as it combines two observations that are routinely undertaken during assessment of patients with TBI.

The GCS-P has also been validated in the paediatric population. Among 2682 patients admitted to a paediatric intensive care

unit, the GCS-P was strongly predictive of mortality and poor functional outcome at discharge among patients with severe TBI.[11]

The GCS-P, through its simplicity to calculate, is more appealing than other scores for clinical use. The IMPACT score combines age, the GCS motor score, pupillary activity, physiological variables, CT brain findings and blood test results for predicting outcomes at discharge and at 6-months after TBI. APACHE II is a common tool to adjust for differences in early intensive care and illness of severity in patients treated in the ICU, including those with TBI. Other scores such as the SAPS II (Simplified Acute Physiology Score II) and SOFA (Sequential Organ Failure Assessment) have also been used to predict outcomes after TBI.[11] The complexity of scores using multiple variables may offer higher predictive performance in some settings but are not feasible for use during trauma reception and resuscitation.

There is opportunity for combination of the GCS-P to other scores to provide more sophisticated prognostic models after TBI. For example, the Marshall classification of TBI is a CT-scan derived metric to predict outcomes in patients with TBI.[12] Combining this score with physiological parameters of the GCS, blood pressure and respiratory rate have been suggested to improve the prediction of outcome in moderate and severe TBI patients.[12] Similarly, combining the APACHE II with the IMPACT score improved 6-month outcome predictive performance.[11] It is therefore possible that prediction of outcomes after TBI could be further improved. However, care should be afforded to maintaining simplicity of measurements for repeated and reproducible measurements at multiple time-points of the patient's journey.

The GCS is most valuable when changes over time are considered. An up-trending GCS is predictive of improved outcomes. It has been suggested that patients with an initially high GCS that remains high have the best outcomes.[13] The value of longitudinal measurements trend of GCS-P has not been evaluated to date and presents and avenue of further research.

The limitations of the study included a retrospective study design and was undertaken using data from a single trauma centre. Thus, this effects the external validity and generalisability of the study findings to other institutions. The outcome measure was assessed at hospital discharge and the GCS-P may provide predictive capabilities over longer time periods that require further exploration. Pupillary response and GCS were evaluated at different time-points (pre-hospital and on hospital arrival), and results may be different if observations were recorded at the same time-point. However, pupillary responses in the pre-hospital phase of care were not commonly recorded and the GCS on arrival at the hospital was commonly altered by medications, particularly for the population with severe TBI. Observations at the different time points were therefore assumed to be the best reflection of injury severity.

While observations of the GCS are expected to be generalisable, the accuracy of the pupil response can vary with low interrater reliability among diverse practitioners performing a manual pupillary exam.[14] Future studies need to standardise the assessment of pupillary function in order to provide higher reliability and validity. The addition of pupillary scores to trauma registries and surveillance of the GCS-P over time would be of further benefit to assess its utility in clinical practice.

Conclusions

The GCS-P was a significantly better predictor of mortality compared to the GCS. As the GCS and pupillary response are routinely measured during assessment of patients with TBI, we recommend adoption of the GCS-P as a single measure of brain injury severity during trauma reception and resuscitation.

Disclosure statement

The authors have no conflicts of interest to declare.

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