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Identification of Demographic and Clinical Prognostic Factors in Traumatic Intraventricular Hemorrhage

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Abstract

Background/Objective.—The presence of traumatic intraventricular hemorrhage (tIVH) following traumatic brain injury (TBI) is associated with worse neurological outcome. The mechanisms by which patients with tIVH have worse outcome is not fully understood, and outcome prediction in these patients is challenging. This study aimed to further identify and characterize demographic and clinical variables that may be implicated in tIVH outcome.

Methods.—In this observational study, we reviewed a large prospective TBI database to determine variables present upon admission that predicted neurological outcome 6 months after injury. A review of 7,129 patients revealed 211 patients with tIVH on admission and 6-month outcome data. Hypothesized risk factors were tested in univariate analyses with significant variables ($p<0.05$) included in logistic and linear regression models. Following addition of either the Rotterdam CT or Glasgow Coma Scale (GCS) scores, we employed a backward selection process to determine significant variables in each multivariate model.

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Authorship contributions: **Abby Scurfield:** conceptualization, investigation, writing – original draft preparation, visualization, funding acquisition. **Machelle Wilson:** methodology, formal analysis, writing – review & editing. **Gene Gurkoff:** conceptualization, writing – review & editing, supervision. **Ryan Martin:** writing, review & editing. **Kiarash Shahlaie:** conceptualization, data analysis/ interpretation, writing, review & editing, supervision, project administration.

The authors declare that they have no conflicts of interest.

Results.—Our study found that that hypotension (OR=0.35, 95% CI=0.13-0.94, p=0.04) and hemoglobin level (OR=1.33, 95% CI=1.09-1.63, p=0.006) were significant predictors in the Rotterdam model, while only hemoglobin level (OR=1.29, 95% CI=1.06-1.56, p=0.01) was a significant predictor in the GCS model.

Conclusions.—This study represents one of the largest investigations into prognostic factors for tIVH and demonstrates that admission hemoglobin level and hypotension are associated with outcomes in this patient population. These findings add value to established prognostic scales, inform future predictive modeling studies, and may provide potential direction in early medical management of patients with tIVH.

Keywords

TBI; intraventricular hemorrhage; trauma; prognostic model

Introduction.

TBI is a well-known and significant cause of morbidity and mortality, and the incidence has been rising (1). TBI is typically characterized by subarachnoid hemorrhage (SAH), subdural hemorrhage (SDH), or epidural hemorrhage (EDH) which represent the most common post-trauma CT findings. Traumatic intraventricular hemorrhage (tIVH) has a reported incidence ranging from 1.7-22% of patients with moderate to severe head injury, representing a less common, but significant enough complication to warrant exploration (2, 3, 4, 5, 6). Studies on tIVH are challenging and currently limited due to data availability (7).

IVH is often a secondary finding to SAH or IPH, representing diffusion of blood from an adjacent hemorrhage (7, 8, 9), whereas primary or isolated tIVH is very rare. Many of the pathologic sequelae of IVH have the potential to cause rapid neurologic deterioration, reflected by mortality rates for tIVH ranging from 21-80% and rates of functional recovery reported at 30 and 40% (2, 7, 10, 11). Interestingly, however, there is debate in the literature regarding the predictive value of tIVH on mortality. Some have reported that tIVH itself is not an independent predictor of mortality, strengthened by a separate finding that patients presenting with isolated tIVH had good outcomes (2, 9). Based on other findings that tIVH was significantly associated with mortality (7, 9, 12), Maas et al. (2005) proposed the addition of tIVH to the Marshall CT Score criteria, leading to the development of the newer Rotterdam Score, underscoring the importance of tIVH to outcome (13).

The potential of tIVH to affect clinical outcome has been strongly documented, but further exploration of possible driving factors for tIVH-associated mortality or poor functional outcome is warranted. The objective of this observational study was therefore to identify prognostic factors within this patient population that may aid in future model development and to highlight variables with potential for clinical intervention in this unique patient population (7, 14). To accomplish this objective, we reviewed detailed admissions data from a large institutional TBI database to determine the predictive variables of and risk factors associated with poor outcome in tIVH. Based on prior TBI studies, we hypothesized that clinical findings of hypotension, hypoxia, hyperglycemia, anemia and elevated INR and demographics such as older age, lower education level, and black race may be

predictive of poor outcome (15, 16, 17, 18, 19). While the following associations are less robustly explored, we also hypothesized that patients with sodium dysregulation (hypo- or hypernatremia) and hyperthermia would demonstrate worse outcomes (20, 21). Based on the unique pathophysiology of IVH, and contrary to previous TBI studies, we hypothesized that platelet levels may be inversely associated with outcomes in this patient population (18, 22).

Methods.

Database.

Subjects were selected from the Traumatic Brain Injury Registry from the University of California, Davis Department of Neurological Surgery ranging from 2008-2020. The registry captures all adult and pediatric patients that present to the hospital with a history of trauma and one of the following: (1) abnormal head computed tomography (CT) scan findings, and/or (2) persistent abnormal neurological examination. Datapoints gathered at the time of admission include demographics, mechanism of injury, CT scan findings, Rotterdam and Marshall CT scores, Glasgow Coma Scale (GCS) score, vital signs, electrolytes, and coagulation profiles. 3- and 6-month Glasgow Outcome Scale (GOS) were then gathered during follow-up. Study data were collected and managed using REDCap (Research Electronic Data Capture) electronic data capture tools hosted at UC Davis Medical Center (23, 24). REDCap is a secure, web-based software platform designed to support data capture for research studies, providing 1) an intuitive interface for validated data capture; 2) audit trails for tracking data manipulation and export procedures; 3) automated export procedures for seamless data downloads to common statistical packages; and 4) procedures for data integration and interoperability with external sources. On average, approximately 600 patients are added to this registry each year, and the database currently has over 7,000 patients. Due to the de-identification of patients included in the database and the absence of author involvement in original data collection and database creation, the UC Davis IRB administration deemed this study exempt from IRB approval. Institutional approval for the TBI registry was pre-existing.

Subjects and Variables.

All patients who presented with tIVH on admission and had associated 6-month follow up data were included in the study. All other patients without tIVH or 6-month GOS data were excluded. Subjects were grouped based on GOS at six months, with scores of 1 - 3 defined as unfavorable (case group), and scores of 4 or 5 as favorable (control group). Demographic variables included: gender, age, race, ethnicity, education level (≤high school or ≥college) and transfer from an outside hospital. Clinical variables recorded at the time of admission included: hypoxia (SaO_2<90%), hypotension (SBP<90mmHg), temperature, sodium, glucose, hemoglobin, INR, platelets, injury type (blunt or penetrating), GCS and Rotterdam scores. Specific injury mechanism data for each patient was explored previously, and because there were no significant differences between specific injury mechanism groups, we reduced the population to two general injury mechanism groups (penetrating and non-penetrating). Continuous numeric variables were age, hemoglobin, INR, GCS, and Rotterdam score. All other variables were either originally categorical or recoded according to appropriate clinical cut-offs to avoid non-linearity. Rotterdam scores were

calculated based on CT scan review by the neurosurgical consultant. All scan findings were documented by the resident physician and then reviewed and confirmed by the attending neurosurgeon. An internal validation study found no significant differences in CT scan findings across residents throughout the department. All patients represented in the database were managed according to published guidelines by the Brain Trauma Foundation. Surgical care was provided by board-certified neurosurgeons (n=11), and post-surgical intensive care was provided by board-certified neurointensivists (n=3).

For univariate analyses, missing values for independent variables were removed from analysis, but these numbers did not exceed five data points for any one variable. Any data points with education response of “unknown” were also removed due to the inability to draw useful conclusions from this category. This resulted in a final sample size of 129 for the univariate analysis on education level, while all other variables included in the univariate analyses maintained a sample size of 211. For the multivariate analyses, removal of data points with the “unknown” education response resulted in total sample sizes of 127 for the Rotterdam model and 129 for the GCS model (figure 1).

Statistical Analysis.

The primary outcome of this study was 6-month GOS. All analyses were performed for both dichotomous outcome and ordinal GOS score. Univariate analyses were conducted to identify associations between covariates and GOS using either the Wilcoxon two-sample test, Chi-square test, or Fisher’s Exact test, as appropriate. Specifically, the Fisher’s exact test was used for variables with groups with small sample sizes (<5), including temperature, sodium, glucose and platelets. All other categorical variables with adequate group sizes were analyzed using the Chi-square test. Continuous and ordinal variables (age, hemoglobin, INR, GCS and Rotterdam) were analyzed using the Wilcoxon Rank Sum and two-sample test. Significant covariates identified in the univariate analyses ($p<0.05$) were included in multivariable logistic and linear regression models for dichotomous and ordinal GOS outcome, respectively. Following creation of these models, GCS and Rotterdam scores were added separately (to avoid multi-collinearity) to each model to assess improvement in predictive ability via the c-statistic. All analyses were performed using SAS® software version9.4 for Windows®(SAS Institute Inc, Cary, NC).

Results.

Of the 7,129 patients in the database, 3.6% (256 patients) presented with tIVH on admission and were included in the study. The patients with tIVH demonstrated a higher mortality rate (37.3%) compared to all other patients without tIVH (11%). Of the 256 tIVH patients, 29% (74 patients) had isolated tIVH. The remaining subjects had one or more concurrent intracranial hemorrhage patterns. Forty-five subjects were lost to follow-up, resulting in absence of GOS outcome data and exclusion from the study. Of the remaining 211 subjects, 69.7% (147) had an unfavorable outcome, while 30.3% (64) had a favorable outcome. Univariate analyses revealed that patients with unfavorable outcome demonstrated higher rates of penetrating injury, lower education level, hypothermia, hypotension, hypoglycemia, and low platelets. For continuous variables, median hemoglobin and INR were lower and

higher, respectively, in patients with unfavorable 6-month GOS. Age, gender, race, ethnicity, transfer from outside hospital, and sodium level did not significantly differ by GOS status (Table 1).

Following backward selection of variables after addition of the Rotterdam score to the logistic regression model, hypotension and hemoglobin remained significant predictors of 6-month outcome, along with the Rotterdam score (figure 2). Patients with hypotension were 65% less likely to have a good outcome at six months (OR=0.35), compared to those patients without, and for each 1g/dL increase in hemoglobin, the odds of a good outcome increase by 33% (OR=1.33). The c-statistic for this model was 0.75, showing improvement from the univariate Rotterdam model (c-statistic=0.70). Using a similar backward selection of variables after addition of GCS score, hemoglobin (OR=1.29) remained a significant predictor with GCS (OR=1.14), revealing a relationship between hemoglobin and GOS consistent with that seen in the Rotterdam model. The c-statistic for this logistic model was 0.71, lower than that of the univariate GCS model (c-statistic=0.78). Results for linear regression models can be found in supplementary materials.

Discussion.

In this study, the percentage of patients with tIVH on admission (3.6%) is consistent with previous reports supporting the rarity of this intracranial hemorrhage (ICH) pattern (7, 10, 6). The higher mortality rate (37.3%) for tIVH patients versus those without tIVH (11%) is also reflective of what many other studies have reported with regards to tIVH outcome (7, 9, 10). The distribution between poor (69.7%) and favorable (30.3%) outcomes within tIVH patients is also similar to the mortality or functional outcome rates for tIVH reported by others (62.5% and ~40-50%, respectively) (7, 11, 25). With regards to our objective to identify potential prognostic factors within tIVH patients, we determined that hemoglobin level and hypotension were significant variables in tIVH prognostication and may add value to established prognostic scores in TBI. This study represents one of the few to comprehensively explore potential driving factors of the high mortality rates associated with tIVH.

In univariate analyses, demographic factors did not differ significantly between outcome groups, with the exception of education level. This contrasts with other studies that have named age, sex, and race as predictors of outcome (7, 26, 27, 28, 16). The TBI IMPACT study on demographics, however, did report education level as an independent predictor of TBI outcome overall, supporting our finding of its significance in both the univariate analyses and the multivariate linear model (16). The association between education level and TBI outcome is well documented, with the majority of studies supporting the positive association seen here (16, 29, 30). Education level has been proposed as a proxy for cognitive reserve (CR), representing cognitive ability independent of the effects of advancing age or brain pathology (30). The underlying mechanisms for the associations between CR and outcome after brain injury have been hypothesized to be related to the protective effects of synapse number and greater ability to recruit backup networks during the recovery process; accordingly, many of the CR studies investigate the relationship between education and *functional* outcome using more granular scales (GOS-E, MMSE,

FSE), not necessarily the 5-point GOS (30, 31). This is important to keep in mind when considering the results of our study – it is not possible to determine whether education level is associated with a better chance of recovery from injury (represented by higher proportion of patients with favorable outcome in univariate analyses), or whether this association merely reflects higher post-injury cognitive function captured within the subjective GOS scores of 4 or 5 (32). Also importantly, education level was not significant in the multivariable logistic model, only univariate and linear analyses. Either way, the influence of education level on outcome is a relatively consistent finding in TBI outcome research, and the mechanisms remain poorly understood, thus encouraging further investigation.

Other significant variables in the univariate analyses included injury type, hypoxia, hypotension, temperature, glucose, platelets, hemoglobin, INR, and GCS and Rotterdam scores. All of these have been implicated in previous TBI outcome studies, but to our knowledge, this is the first study to investigate these factors, with the exception of injury type, specifically in patients with tIVH (17, 33, 5). We demonstrated that patients with poor outcome had higher proportions of penetrating injury (vs. blunt), hypoxia, hypotension, hypothermia, hyperglycemia, thrombocytopenia, lower hemoglobin, and higher INR compared to patients with good outcome, findings that are comparable to associations reported in prior papers on TBI (9, 17, 18, 34). The 45 patients with hypoxia included in our sample represent an interesting subset. Because our database does not include documentation of mechanism of injury, it is difficult to assess cause of reported hypoxia, but because this is a measurement of systemic oxygenation, a likely possibility is that these patients may have incurred more extensive injuries causing extensive blood loss or airway obstruction (35). If this is the case, extracranial injury could represent a significant confounding variable contributing both to hypoxia and likelihood of poor outcome. With regards to the significance of temperature and our finding that 100% of our 26 patients with hypothermia demonstrated poor outcome, it is certainly possible that their hypothermia may have been due to cardiac arrest. It is important to note, however, that hypothermia can be a frequent finding on admission at our institution, possibly due simply to exposure to yearly temperatures ranging from 39 to 94 °F. If due to cardiac arrest, this would also represent a confounder and potentially explain why it did not maintain significance when examined alongside other variables, such as GCS, hypoxia, and hypotension.

Coagulation factors have been minimally studied in tIVH, and our interest in baseline platelet level and INR stemmed from the unique physiology of IVH (15). Although based on patients with non-traumatic IVH, Ziai et al. (2012) reported an independent effect of platelet count on IVH clot lysis rates in both recombinant tissue plasminogen activator (rt-PA) and placebo treated patients, with lower baseline platelet count associated with more rapid clot lysis, suggesting that baseline platelet level influences clot lysis independently of rt-PA treatment (22). We were interested to see whether this finding might be reflective of underlying IVH pathophysiology and therefore hold true in our tIVH cohort. In our study, however, thrombocytopenia was associated with poor outcome in univariate analyses. This finding, in addition to the association of higher INR with poor outcome may simply reflect contributions to IVH volume, a factor shown to be independently related to outcome in both traumatic and spontaneous IVH, and not necessarily an effect on clot dissolution which would mediate outcome in the opposite direction (14, 22). With the exception of hemoglobin

and hypotension, however, none of the other covariates listed above remained significant in multivariate models.

GCS and Rotterdam scores are widely used prognostic indicators in TBI (13, 36). In multivariate analyses, we were interested in both the identification of independent risk factors for poor outcome and determination of whether these variables would add power to the baseline prognostic value of the Rotterdam and GCS scores. The univariate logistic models for both the Rotterdam (OR 0.23) and GCS (OR 1.24) scores alone confirmed their significance as strong outcome predictors, in line with Fujimoto et al. (2016) who report a similar OR for the association between initial Rotterdam score and unfavorable outcome (GOS 1-3) (37). Following backwards selection, hemoglobin level remained significant in the logistic GCS model, and both hemoglobin level and hypotension remained significant in the logistic Rotterdam model. The increase in the c-statistic of the Rotterdam model from 0.70 to 0.75 represents a significant increase in predictive value with the addition of hemoglobin and hypotension as prognostic factors. Hemoglobin also remained significant in the GCS model, but the c-statistic fell from 0.78 to 0.71.

The relationship between anemia and TBI outcome has been inconsistent and controversial, with some studies documenting higher rate of poor outcome (38, 39, 40), others showing a lack of association (41), and yet another demonstrating that the relationship between anemia and TBI outcome is mediated by brain tissue oxygen tension ($PbtO_2$), therefore suggesting that anemia is not an independent predictive factor (42). Due to the retrospective nature of our study, it is difficult to interpret the significance of hemoglobin level with much granularity since it was a one-time measurement and we lack transfusion and $PbtO_2$ data. We can say, however, that admission hemoglobin level is a prognostic factor when controlling for baseline injury markers and secondary insults such as hypotension and general hypoxia. It may serve as an informative baseline outcome predictor and is already included in validated TBI outcome algorithms, but this study confirms its significance in tIVH specifically (39).

Hypotension is one of the most widely documented harbingers of poor outcome in TBI research in general (8, 17, 43, 44). In our study, hypotension was an independent predictor of poor outcome in the Rotterdam model, but not in the GCS model, indicating it is a helpful factor to consider for prognosis in conjunction with Rotterdam scores, but its predictive effect becomes buried with simultaneous consideration of GCS. It is known that secondary insults, such as hypotension, lower the GCS score if blood pressure is recorded before patients are stabilized, so this may explain its lack of significance in the GCS model (45). Prior studies have established early hypotension as a major contributor to secondary brain injury following TBI, and others show a strong relationship between persistence of hypotension and mortality (46, 47, 48). These findings, in combination with our own identification of hypotension as an independent risk factor in the Rotterdam model, corroborate the critical importance of blood pressure management in TBI patients. The identification of this variable is not only informative when considering patient prognosis but even more noteworthy due to its modifiable nature. Further studies have focused on the importance of management of pre-hospital, ED, ICU, and intraoperative blood pressure, with

one confirming that prehospital treatment of TBI patients with hypotension was associated with significantly improved outcomes (44, 47, 49, 50, 51).

This study is limited by several factors - namely, the moderate sample size, retrospective design, and decision not to create two subgroups of patients with secondary vs. primary tIVH. The rarity of tIVH in general necessitated the use of a large TBI database to arrive at an adequate sample size, and the retrospective case-control design was a logical choice for our research question. We were able to garner a larger sample size than other publications on tIVH which have used samples ranging from 16 to 117 (7, 11, 25). Still, upon grouped univariate analyses, some group sizes became very limited, particularly discretized variables such as temperature, glucose, and platelets. In multivariate analyses, we made the decision to eliminate the “unknown education” category due to associated difficulty drawing meaningful conclusions, but this resulted in a significant reduction in our study group since 129 patients fell into this category. Due to the retrospective nature of the data, imputation techniques were not used to address this issue. Importantly, however, we were able to run probabilistic statistics that even the largest tIVH study lacks, which is more descriptive in nature (7). Our results could be greatly strengthened by the addition of an external cohort for validation, allowing for a greater sample size and generalizability, and this is certainly something to consider to further the reach of the current study. The retrospective design of our study also naturally renders conclusions on directionality and causality difficult to make. This is further complicated by the lack of access to additional data — information on timing of vitals and their temporal relationship to GCS calculation, patient transfusion status, serial CT findings, and neurosurgical intervention would have allowed us to explain potential interactions between vitals and GCS, explore the effects of transfusion on outcome in patients with low hemoglobin, and delineate the effects of dynamic IVH CT findings and neurosurgical intervention on outcome. We must also acknowledge the lack of data regarding IVH volume and mortality upon the time of discharge or due to withdrawal of care. The Graeb score, a quantitative tool for IVH measurement and outcome prediction, has been validated in prior IVH research, but until recently has not been used specifically in tIVH studies (52, 53). Due to the lack of prior validation in our specific population and lack of data on ventricular blood volumes in our database to calculate Graeb scores, we were unable to include this factor as a variable in our models. Lastly, data on withdrawal of care and mortality upon discharge naturally would better contextualize our results and represent two variables for further exploration.

Finally, there is controversy in the literature over the differential outcomes of patients with isolated vs. secondary tIVH. Many studies have reported that high mortality rates in tIVH are more reflective of trauma severity rather than an independent effect of ventricular bleeding and that patients with isolated tIVH typically have better outcomes than those patients whose IVH developed as a result of primary ICH expansion (11, 25). Therefore, it is possible that tIVH is not an independent outcome predictor. Nevertheless, IVH introduces a separate type of pathophysiology and associated mechanism for neurologic compromise, namely ventricular clot formation and subsequent obstructive hydrocephalus, rendering it crucial to not simply consider these cases of “severe TBI.” For a subtype of ICH with such poor outcome statistics and unique physiology, literature on prognosis in tIVH is scarce. Existing studies are limited by small sample sizes and a focus on relatively few variables

in exploration of outcome within tIVH populations. It is important to explore the driving factors of poor outcome because they may differ from patients without this pathology. That brings us to the suggestion for future work to focus on further delineation of risk factors in each subtype of TBI, in addition to grouped studies of patients with and without tIVH. Despite the above limitations, we have still brought to light interesting associations between hemoglobin level and hypotension and tIVH outcome while controlling for many potential confounders. Research cited above has added to our understanding of the directionality of these associations, but this study was the first to even document them in patients with tIVH.

Conclusions.

The current study is the first to undertake a comprehensive approach to the identification of prognostic factors for tIVH. In the future, this study would benefit greatly from external validation with involvement of additional centers, and if results are validated, they may guide future considerations in prognostic study design, patient and family counseling, and clinical management. While future prospective studies are needed to elucidate the directionality and mechanisms of the relationships identified in this report, this study adds foundational knowledge to the growing understanding of tIVH outcomes and mitigates the dearth of research on this subject.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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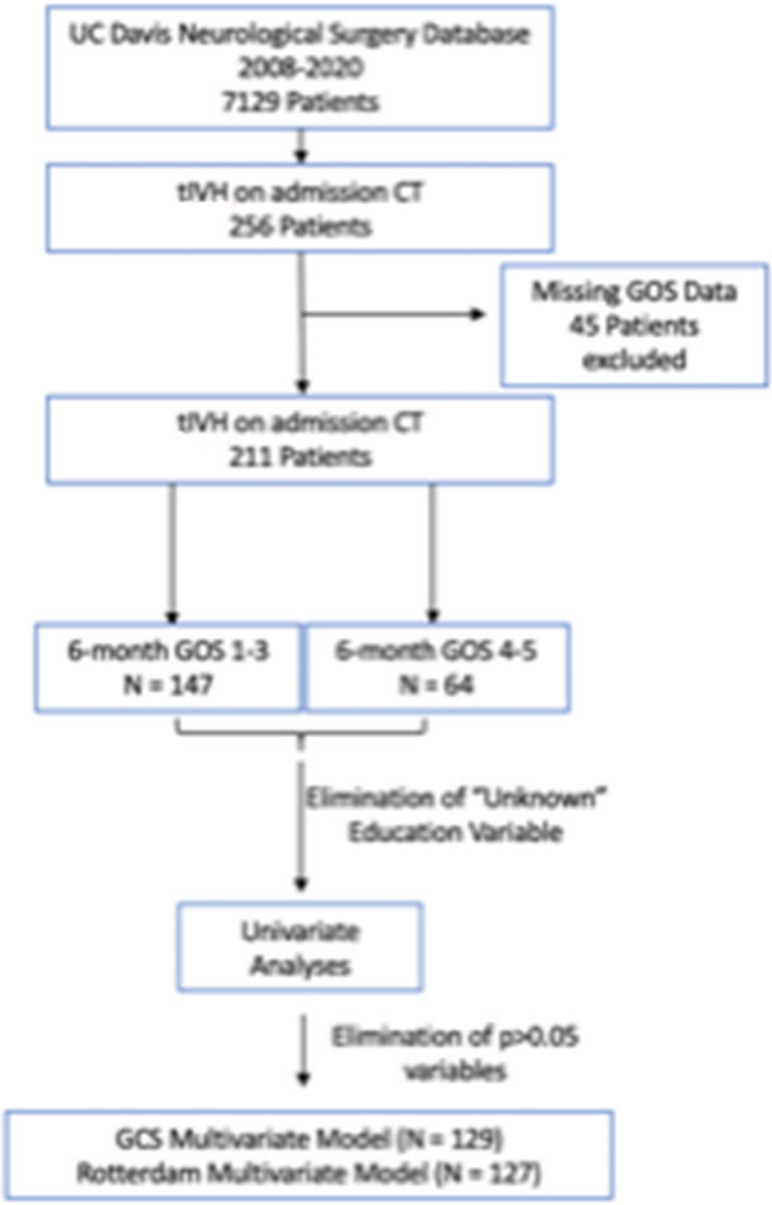

Figure 1.
Flow chart detailing sample size determination and statistical analyses.

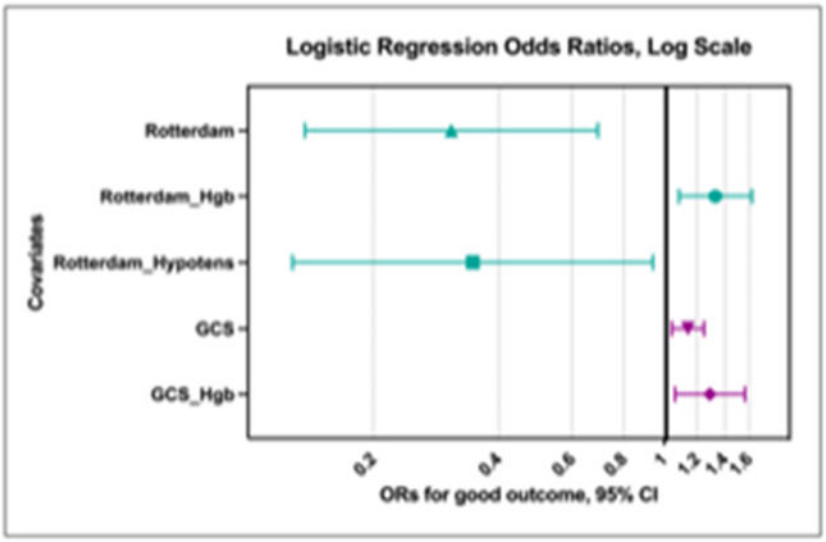

Figure 2.

Forest plot showing odds ratios for association between covariates and GOS 4-5 at 6 months for both Rotterdam and GCS logistic regression models. Error bars represent 95% CI. “Rotterdam” – Rotterdam score in the Rotterdam model. “Rotterdam_Hgb” – hemoglobin in Rotterdam model. “Rotterdam_Hypotens” – hypotension in Rotterdam model. “GCS” – GCS score in GCS model. “GCS_Hgb” – hemoglobin in GCS model.

Table 1.

Results of univariate analyses for baseline demographic and clinical variables by 6-month GOS

		6 month GOS		P-value
	All Patients (n = 211)	**Unfavorable (1-3) (*n = 147*)**	**Favorable (4-5) (*n = 64*)**	
Data at presentation, n (%)				
Age	50.0 (26.0-73.0)	55 (28-77)	48 (23-63)	0.11
Gender				0.05
Male	154 (73.0)	113 (73.4)	41 (26.6)	
Female	57 (27.0)	34 (59.6)	23 (40.4)	
Race				0.40
Caucasian	151 (71.6)	101 (66.9)	50 (33.1)	
African American	20 (9.5)	15 (75.0)	5 (25.0)	
Other	16 (7.6)	11 (68.8)	5 (31.4)	
Unreported	24 (11.3)	20 (83.3)	4 (16.7)	
Ethnicity				0.52
Non-Hispanic	157 (74.4)	109 (69.4)	48 (30.6)	
Hispanic	38 (18.0)	25 (65.8)	13 (34.2)	
Unknown	16 (7.6)	13 (81.3)	3 (18.8)	
Education †				0.004 *
≤High School	84 (65.1)	56 (66.7)	28 (33.3)	
≥College	45 (34.9)	18 (40.0)	27 (60.0)	
Transfer	82 (38.9)	59 (72.0)	23 (28.0)	0.57
Injury Type				0.005 *
Blunt	189 (89.6)	126 (66.7)	63 (33.3)	
Penetrating	22 (10.4)	21 (95.5)	1 (4.6)	
Hypoxia	45 (21.3)	43 (95.6)	2 (4.4)	<0.001 *
Hypotension	77 (36.5)	66 (85.7)	11 (14.3)	<0.001 *
Temp				<0.001 *
Hypothermia (<35°C)	26 (12.4)	26 (100.0)	0 (0.0)	
Normal (35-37.9°C)	179 (85.2)	119 (66.5)	60 (33.5)	
Hyperthermia (≥38°C)	5 (2.4)	1 (20.0)	4 (80.0)	
Glucose				0.03 *
Low (<70)	1 (0.5)	0 (0)	1(100)	
Normal (70-200)	166 (79.8)	111 (66.9)	55 (33.1)	
High (>200)	41 (19.7)	34 (82.9)	7 (17.1)	
Sodium				1.00
Low (<136)	35 (16.8)	24 (68.6)	11 (31.4)	
Normal (136-145)	169 (81.3)	118 (69.8)	51 (30.2)	
High (>145)	4 (1.9)	3 (75.0)	1 (25.0)	
Platelets				0.02 *

		6 month GOS		P-value
	All Patients (n = 211)	**Unfavorable (1-3) (*n = 147*)**	**Favorable (4-5) (*n = 64*)**	
Low (<150)	50 (23.7)	42 (84.0)	8 (16.0)	
Normal (150-400)	155 (73.5)	102 (65.8)	53 (34.2)	
High (>400)	6 (2.8)	3 (50.0)	3 (50.0)	
Hemoglobin	12.5 (10.8-14.0)	12.35 (10.8-13.8)	13.35 (10.95-14.85)	0.008 *
INR	1.07 (1.0-1.22)	1.11 (1.02-1.35)	1.03 (0.98-1.13)	<0.001 *
GCS	9.0 (5.0-14.0)	7 (3-12)	14 (9-15)	<0.001 *
Rotterdam	3.0 (3.0-4.0)	3 (3-4)	3 (3-3)	<0.001 *

GOS - Glasgow Outcome Scale, INR - international normalized ratio, GCS - Glasgow Coma Scale

Continuous variables reported with median (IQR)

* Significant variables included in multivariate models ($p<0.05$)

† Education level sample size = 129, due to elimination of “unknown” category