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## Injury severity variables as predictors of WeeFIM scores in pediatric TBI: Time to follow commands is best

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### Abstract

After pediatric traumatic brain injury (TBI), early prognosis of expected function is important for optimizing care. The power of several common brain injury severity measures for predicting functional outcome in children with TBI was investigated; the severity variables studied were Glasgow Coma Scale (GCS) score, time to follow commands (TFC), duration of post-traumatic amnesia (PTA), and total duration of impaired consciousness (TFC+PTA). Outcome was assessed using the Functional Independence Measure for Children (WeeFIM) at discharge from inpatient rehabilitation ( $n = 120$ ) and, in a subset of children, at 3 months following discharge. Correlations and multiple linear regression analyses were conducted using GCS, TFC, PTA, and TFC+PTA to predict age-corrected WeeFIM scores. Models in which TFC and PTA duration were entered as separate variables and as a combined variable (TFC+PTA) were all significantly predictive of WeeFIM scores at discharge; however, TFC accounted for the greatest portion of variance in WeeFIM scores. Among children with moderate to severe TBI who received inpatient rehabilitation, TFC was the best predictor of general functional outcome at discharge and follow-up. Our findings highlight the need for careful and consistent assessment of TFC to assist in predicting functional outcomes as early and accurately as possible.

### Keywords

Traumatic brain injury; children; outcome; coma; post-traumatic amnesia

## 1. Introduction

Functional outcome varies notably after moderate to severe childhood traumatic brain injury (TBI), even for the subset of children requiring inpatient rehabilitation [41]. Nonetheless, accurate prediction of outcome for this group of children is essential for appropriate planning for school re-entry, outpatient therapy, and for guiding expectations of family and community members. Furthermore, accurate prediction of functional outcome facilitates focusing of therapeutic interventions and may improve the efficiency and efficacy of delivery of rehabilitation services. A number of injury-related variables have been identified as useful predictors of functional outcomes after TBI and may be useful for anticipating outcome in children receiving inpatient rehabilitation after TBI. The purpose of this study was to evaluate several measures of TBI severity in order to identify the best predictor with regard to functional outcome in children with TBI. The predictors examined (Glasgow Coma Scale score, time to follow commands, duration of post-traumatic amnesia, and total duration of impaired consciousness) and relevant prior work are reviewed below.

### 1.1. Glasgow coma scale score

The Glasgow Coma Scale (GCS) [48] is a widely used measure of TBI severity. Originally introduced in 1974, the GCS provides a rapid, easily obtained measure of level of consciousness based on visual, motor, and verbal responses and continues to be used for clinical assessment and prognosis. In adults, GCS is predictive of a number of functional outcome variables at short and long term follow-up after TBI [8,22,35,38,52].

Early GCS score is also predictive of functional outcomes in children with TBI. Several studies have examined GCS scores obtained at various time points in the acute stage of TBI, ranging from emergency room admission to 72 hours post injury and have identified predictive relationships between GCS and global functional outcome {based on the Glasgow Outcome Scale (GOS) [17]} at hospital discharge [10,30,37], 6 months post-injury [6,10], 1 year post-injury [35,38,49], and several years after injury [7]. Early GCS has also been shown to be predictive of more specific functional outcomes after childhood TBI. For example, GCS predicts performance on neuropsychological testing both within weeks of emergence from post-traumatic amnesia [22,28] and at one year post-injury [28,51].

While GCS score is an important predictor of functional outcome after TBI, variability in pre-hospital care and timing of attainment of GCS may impact assigned scores [26]. In isolation, this tool has limitations in its ability to consistently and accurately predict subsequent outcome, especially as neuroresuscitative methods continue to improve [25]. Alternative measures of brain injury severity which quantify duration of impaired consciousness capture the trajectory of recovery and thus offer additional information not provided by one early GCS score. These variables include time to follow commands (TFC) and duration of post-traumatic amnesia (PTA).

### 1.2. Time to follow commands

Time to follow commands (TFC) is the duration of time between injury and demonstration of ability to follow simple motor commands. In adults with TBI, TFC predicts global outcomes at acute care discharge [11,50] and 6 months post-injury [11,18]. TFC has also been found to predict more specific functional outcomes in adults, including Functional Independence Measure (FIM, Uniform Data System for Medical Rehabilitation, Buffalo, NY) total score at inpatient rehabilitation admission and discharge as well as acute care and rehabilitation lengths of stay [50].

The literature regarding the utility of TFC as a predictor variable in childhood TBI is more limited. TFC has been shown to predict motor outcomes one year after injury in children [4]. In addition, in a mixed sample of adults and children, TFC was predictive of global outcome, based on the GOS, at 12 months after injury [19].

Studies examining both GCS and TFC as predictors of outcome provide conflicting evidence regarding which variable has better predictive power. Katz et al. found that TFC was superior to GCS in predicting outcome, using the GOS, at both 6 and 12 months post-injury in a combined sample of children and adults [19]. In contrast, McDonald et al. found, in children, that GCS was more predictive than TFC of neuropsychological function during acute recovery from injury [28]. Likewise, Poon et al. reported that GCS, but not TFC, was an independent predictor of outcome at one year, using GOS, in adults [38].

### 1.3. Duration of post-traumatic amnesia

Duration of post-traumatic amnesia (PTA) is another measure of duration of impairment in consciousness. PTA refers to the period after TBI during which an individual demonstrates inability to store and recall new information [44]. The end of PTA is typically determined through use of serially administered standardized measures which evaluate orientation and new learning. In adults, the Galveston Orientation and Amnesia Test (GOAT) was developed for this purpose [24,53], and the Children's Orientation and Amnesia Test (COAT) [13] was later developed for use in children. When using duration of PTA as a predictive variable, some authors consider entire time since injury to emergence from PTA (e.g., [5,19,28]), while others consider only the duration of time from command following to emergence from PTA (e.g., [11,13,24]). Here, we define PTA as the time from command following to emergence from post-traumatic amnesia and use the abbreviation TFC+PTA to refer to the total duration of time from injury to emergence from post-traumatic amnesia.

Duration of PTA, defined as the interval from TFC to ability to store and recall new information, has been shown to be useful in predicting outcomes in adults and children. PTA was shown to predict dichotomized global outcome, using the GOS, at least 6 months after injury in adults [24]. PTA was felt to be at least as strongly related as TFC to global functional outcome, as assessed by GOS, at time of acute care hospital discharge and at 6 month follow-up in adults [11]. Furthermore, in children, PTA was found to be a better predictor of memory test performance at 6 and 12 months than GCS [13].

### 1.4. Total duration of impaired consciousness

TFC+PTA, or total duration of impaired consciousness after TBI, has also shown promise in predicting outcomes after TBI in adults. TFC+PTA has been shown to predict cognitive FIM scores at discharge from acute care [8] and FIM and Disability Rating Scale (DRS, [39]) scores at admission and discharge from inpatient rehabilitation [53]. In addition, TFC+PTA has been shown to correlate with employment and emotional outcomes at least one year after adult TBI [29,34].

Total duration of impaired consciousness has shown utility in predicting a range of outcomes after childhood TBI as well. TFC+PTA is predictive of global functional outcome, as measured by the GOS, at hospital discharge and at 3, 12, and 24 months post-injury [42,43]. TFC+PTA has also been shown to predict performance on specific neurobehavioral measures at 3 weeks following normalization of COAT score and at 1 year post-injury [28].

In studies comparing TFC+PTA and other previously discussed predictors of outcome, TFC+PTA has been shown to have predictive power superior to GCS or TFC. In adults, TFC+PTA was better than GCS in predicting cognitive FIM score at discharge from an acute care facility

[8]. TFC+PTA was also better than GCS and slightly better than TFC at predicting FIM and DRS scores at discharge from inpatient rehabilitation and at 1 year follow-up in adults [5]. In a sample of children and adults, TFC+PTA was a better predictor than either GCS or TFC of GOS score at 6 and 12 months post injury [19]. Finally, in children, TFC+PTA was better than GCS or TFC at predicting short and long term neurobehavioral and functional outcomes, based on standardized neuropsychological tests [28].

Total duration of impaired consciousness, or TFC+PTA, appears to be an important predictor of outcomes following TBI. However, there has been no report examining the predictive utility of TFC and PTA separately, using mutually exclusive definitions, and TFC+PTA in combination in predicting functional outcomes in children with TBI, though identifying which of these variables is the best predictor for outcomes would facilitate the ability to provide as accurate a prognosis for functional recovery as possible. The goal of our study was to determine whether GCS, TFC, PTA, or total duration of impaired consciousness, as defined by TFC +PTA, was most predictive of self care, mobility, cognitive, and overall functional status, as assessed with the Functional Independence Measure for Children (WeeFIM, Uniform Data System for Medical Rehabilitation, Buffalo, NY) at time of discharge from pediatric inpatient rehabilitation and at subsequent follow-up. Based on findings from the literature discussed above, we hypothesized that total duration of impaired consciousness, TFC+PTA, would be the best predictor of functional outcomes in children with moderate or severe TBI requiring inpatient rehabilitation.

## 2. Methods

### 2.1. Participants

Data were collected from children admitted to a tertiary-care affiliated acute brain injury rehabilitation unit between January 1998 and November 2008 with moderate to severe TBI, defined as first available Glasgow Coma Scale score of less than or equal to 12 or presence of intracranial trauma-related neuroimaging findings. Children were excluded from the analyses if they were too young for administration of the COAT (less than 3 years old) or if PTA had not resolved at the time of discharge from inpatient rehabilitation. Data were analyzed from 120 children who met the above criteria. Additional analyses were performed on a subset of these children ( $n = 34$ ) for whom follow-up data was available, as described below.

### 2.2. Measures

**2.2.1. Glasgow coma scale (GCS)**—GCS was defined as the earliest available GCS score [48] documented at the scene of injury, in transit, or upon arrival to the Emergency Department. GCS scores were obtained as part of routine clinical care and were collected for this study through medical record review.

**2.2.2. Time to follow commands (TFC)**—TFC was defined as the ability to follow verbal commands twice in a 24-hour period as observed by hospital staff. TFC was obtained based on medical record review if the child began to follow simple, one-step commands prior to admission to inpatient rehabilitation unit or by staff report and documentation of following 2 simple commands during a 24 hour period during the child's rehabilitation admission.

**2.2.3. Duration of posttraumatic amnesia (PTA)**—PTA was assessed with the COAT, a 16-item instrument evaluating general orientation, temporal orientation, and memory [13]. PTA was considered resolved when a child obtained two consecutive scores within two standard deviations of the mean for age on the COAT. As part of clinical care, the COAT was administered once daily by neuropsychology staff until children met the above criteria for emergence from PTA. There were 16 children who were felt to have emerged from PTA at the

time of first COAT administration on the inpatient rehabilitation unit. For 8 of these children, duration of PTA was obtained from chart review based on provider, parent, or child's report of emergence of ability to lay down new memories. For the remaining 8 children who were out of PTA at inpatient rehabilitation admission, duration of PTA could not be definitely determined; in these cases, PTA was assigned to be the number of days between TFC and admission COAT administration (range 5 to 8 days).

**2.2.4. Total duration of impaired consciousness (TFC + PTA)**—TFC + PTA was defined as the sum of the durations of TFC and PTA.

**2.2.5. Functional outcomes**—Functional outcomes were quantified using the Functional Independence Measure for Children (Wee FIM, Uniform Data System for Medical Rehabilitation, Buffalo, NY), an 18-item performance-based instrument that assesses mobility, self-care, and cognitive abilities [32]. The WeeFIM has been validated in children with normal development [31], developmental disabilities [36,54], and acquired brain injury [54]. Several previous studies have utilized the WeeFIM as a measure of functional outcomes in pediatric TBI (e.g. [3,27,41]). While the WeeFIM was initially designed to describe major levels of independence across typically developing children aged 6 months to 8 years [31], it has been validated for use in adolescents with cerebral palsy up to age 16 years [1] and is commonly used to evaluate older children and young adults with a variety of developmental or acquired disabilities [2,45,46], including children with TBI up to 21 years of age [41].

Given the wide age range of children evaluated in the current study (ages 3–18 years old at injury) and the effect of age on WeeFIM ratings in children below the age of 6 years [47] due to the developmental nature of the functional abilities assessed [31], WeeFIM Developmental Functional Quotients (DFQs [33]), were used. DFQs reflect percent of “normal” or “age-appropriate” functioning, allowing comparison across age groups for each WeeFIM functional domain: self-care, mobility, cognitive, and total. Each WeeFIM item is rated on a scale from 1–7, and DFQs can range from 14 (for a child who receives scores of 1 on items for which the age-based norm is 7) to greater than 100 (for a child who performs at a level exceeding the age-based norm). For the purpose of exploratory analyses, total WeeFIM DFQ greater than or equal to 85 (85% of age-appropriate functioning) was considered a “good” outcome, DFQ between 70 and 84 was considered a “moderate” outcome, and DFQ less than 70 was considered a “poor” outcome.

Discharge WeeFIM ratings were obtained by each child's primary therapists just prior to the child's discharge from inpatient rehabilitation. Follow-up WeeFIM ratings were obtained by a private company with trained interviewers using a standardized phone protocol 3 months following the child's discharge from inpatient rehabilitation. As collection of follow-up WeeFIM data was recently adopted as standard practice at our institution, only a subset of children in this cohort has follow-up WeeFIM data ( $n = 34$ ).

### 2.3. Procedure

All data were collected as part of routine clinical care and entered into a program evaluation database. The Johns Hopkins University School of Medicine's Institutional Review Board granted an exempt status approval for a separate research database to be created for this study that was stripped of all patient identifiers and protected health information.

### 2.4. Statistical methods

All statistical analyses were completed using SPSS 16.0 (www.spss.com), and alpha was set at  $p < 0.05$  for all analyses. Descriptive statistics were calculated to examine demographic variables. Bivariate correlation analyses were conducted to investigate relationships between

injury severity variables (GCS, TFC, PTA, and TFC+PTA) and discharge and follow-up WeeFIM variables (Total Self Care DFQ, Total Mobility DFQ, Total Cognitive DFQ, and Total DFQ). Specifically, for each child, the values for the injury severity variables remained constant and were evaluated for correlation with one or two sets of WeeFIM data – one acquired at discharge from inpatient rehabilitation, and, when applicable, another set of WeeFIM data collected 3 months after discharge. Strength of correlations, based on correlation coefficient, was assigned using the following parameters:  $r = 0-0.2$  (very weak),  $r = 0.2-0.4$  (weak),  $r = 0.4-0.7$  (moderate),  $r = 0.7-0.9$  (strong),  $r = 0.9-1.0$  (very strong).

Two sets of hierarchical multiple linear regressions were performed to explore the relationship between the predictor variables and each of the WeeFIM domain scores. Predictor variables for the first set of regressions included GCS, TFC, and PTA. GCS was entered into each model first, followed by TFC, and then PTA. The change in predictive power at each step was evaluated to examine the additional contribution of each variable to the model. A second set of hierarchical multiple linear regressions was performed to examine the predictive power of TFC+PTA on the WeeFIM scores. As in the first set of models, GCS was entered first. The additive predictive power of TFC+PTA was then examined. Given that the number of predictor variables differed between the two sets of regression models and that a larger number of independent predictor variables can inflate  $R^2$ , adjusted  $R^2$  was used to evaluate the relative predictive power of the two sets of regression models [47]. Collinearity statistics were evaluated for each model.

Following identification of the severity variable with the strongest predictive power regarding WeeFIM outcomes, exploratory analyses were performed to identify cut-off points for that severity variable with clinical relevance for predicting good versus moderate versus poor functional outcome based on total WeeFIM DFQ at discharge from inpatient rehabilitation. Cut-off points were chosen such as to optimize the distinction in outcomes between time points.

All relevant analyses were run with the entire cohort and again following removal of the 8 children for whom duration of PTA could not be definitively determined in order to ensure that the proxy PTA values (longest possible PTA) for these 8 children did not drive the reported findings.

### 3. Results

#### 3.1. Description of the sample

Demographic characteristics of the study sample are presented in Table 1. The 120 children ranged in age from 3 to 18 years at the time of injury. Eighty-one were boys (67%); 63 (53%) were Caucasian, and 45 (37%) were African American. Only 5 children had initial GCS > 12; all 5 of these children had documented injury-related neuroimaging findings. For the subset of children with follow-up data ( $n = 34$ ), 21 were boys (62%); 24 (71%) were Caucasian, and 9 (27%) were African American. Three of these children had initial GCS > 12.

#### 3.2. Correlations between injury severity variables and WeeFIM outcomes

To examine the relationship between injury severity variables and WeeFIM outcomes, we first conducted bivariate correlation analyses. Results are reported in Table 2.

Examining discharge WeeFIM data ( $n = 120$ ), GCS was generally weakly correlated with DFQs, TFC was generally moderately correlated with DFQs, PTA was weakly to moderately correlated with DFQs, and TFC+PTA was generally moderately correlated with DFQs. For each WeeFIM domain, correlation with TFC was stronger than that with TFC+PTA. The strongest correlations among injury severity variables and discharge WeeFIM outcomes were



between TFC and total WeeFIM DFQ and WeeFIM Self-care DFQ. For all predictor variables, correlation with Cognitive DFQ was weaker than the correlation with the other DFQs.

Examining WeeFIM data from follow-up 3 months after discharge from inpatient rehabilitation ( $n = 34$ ), GCS was not correlated with any of the WeeFIM outcomes. TFC was generally moderately correlated with DFQs, PTA was generally not correlated with DFQs, and TFC +PTA was weakly-moderately correlated with DFQs. The strongest correlations between injury severity variables and outcomes 3 months after discharge from inpatient rehabilitation were between TFC and Mobility DFQ and WeeFIM Total DFQ. With the exception of PTA, correlation between predictor variables and Cognitive DFQ was again weaker than correlations with other DFQs.

At both time points, the pattern of findings for correlations remained consistent when the 8 children for whom PTA could not be definitively determined were removed from the sample.

### 3.3. Hierarchical regression models

The results of the hierarchical multiple linear regression analyses predicting each of the WeeFIM domain and Total WeeFIM DFQs at discharge and 3 month follow-up are presented in Table 3. Collinearity analyses revealed tolerances close to 1, providing evidence that multicollinearity did not affect these analyses [15].

At discharge ( $n = 120$ ) and 3 month follow-up ( $n = 34$ ), for all models examining the separate contributions of TFC and PTA, TFC contributed significantly to the overall predictive power of the model, whereas PTA added predictive power above and beyond the influence of GCS and TFC only to the model Self-Care DFQ at 3 month follow-up. Comparison of adjusted  $R^2$  values revealed that the models that included TFC and PTA as separate variables consistently explained more variance than the models in which TFC+PTA was examined as one variable, with the exception of the models predicting Cognitive DFQ 3 months after discharge. For the models in which TFC and PTA were entered as separate predictors, overall predictive power of the model was stronger at 3 month follow-up than at discharge. For the models in which TFC+PTA was examined as one variable, the overall predictive power of the models at 3 month follow-up, as compared to the models using discharge data, was stronger for Mobility and Cognitive DFQs but weaker for Self-Care and Total DFQs.

At all time points, the pattern of findings for the regression analyses remained consistent when the 8 children for whom PTA could not be definitely determined were removed from the sample.

### 3.4. Evaluation for TFC values with clinical relevance for predicting functional outcome

As TFC was determined to be the best predictor of WeeFIM outcomes, this variable was further examined for “cut-off” points with regard to broadly categorizing child's functional outcome at discharge from inpatient rehabilitation. There was no value for TFC for which all children had a good functional outcome at discharge. Outcome by TFC is summarized in Table 4. Forty-one percent of children with TFC between 0 and 2 days had a good outcome at discharge, 12% of children with TFC between 3 and 11 days had a good outcome, and no child with TFC greater than 11 days had a good outcome at discharge from inpatient rehabilitation. For each TFC subgroup (0–2 days, 3–11 days, and 12–26 days), children with poor outcomes were younger than children with good to moderate outcomes. For example, for children with TFC 0–2 days, mean age for children with good or moderate outcome was 11.8 years (standard deviation 3.2 years) while mean age for children with poor outcome was 7 years (standard deviation 2.6 years) ( $p < 0.001$ ).

## 4. Discussion

The aim of this study was to determine which severity measure, GCS, TFC, PTA, or TFC+PTA, was most predictive of functional outcome in children with moderate to severe TBI requiring inpatient rehabilitation. Based on the existing literature, we hypothesized that TFC+PTA would be the best predictor. Our results revealed that TFC was the variable that was most strongly related to functional outcome at discharge from pediatric inpatient rehabilitation and at follow-up. TFC was consistently more strongly associated with WeeFIM domain and total DFQs than was GCS, PTA, or TFC+PTA. With respect to the remaining variables, TFC+PTA was also a significant predictor of functional outcome as assessed with WeeFIM domain and total DFQs. However, its relative value was consistently lower than that of TFC, and thus it appeared to be the second best predictor of function at discharge and subsequent follow-up. When examining TFC and PTA separately, PTA was typically not significantly predictive of functional outcome above and beyond the contribution of GCS and TFC. Additionally, in regression models, TFC was consistently a better predictor of WeeFIM outcomes than was TFC+PTA, suggesting that the addition of PTA to TFC adds only statistical noise.

The finding that TFC was a stronger outcome predictor than TFC+PTA is not consistent with findings from the literature. Prior studies demonstrated that TFC+PTA was a stronger predictor than TFC of global outcome at 6 and 12 months post-injury [19] and of specific cognitive and functional outcomes weeks after emergence from PTA and 1 year following injury [28]. Additional work demonstrated that TFC and TFC+PTA were fairly similar in their ability to predict outcomes at inpatient rehabilitation discharge and one year after TBI, however the authors determined that TFC+PTA was a slightly better predictor than TFC alone [5]. Differences between our findings and those previously reported may, in part, be due to differences in participant characteristics and outcome measures.

Participant age is one factor that may contribute to conflicting results between our study and those reported previously. The participants in the current study were children aged 3–18 years at the time of injury, representing a wider age range of children than those studied by McDonald et al., whose participants were 6–15 years old [28]. Given evidence of worse outcomes in the youngest children with diffuse TBI compared with those injured later in childhood [9,12,20], our inclusion of pre-school age children may have impacted our findings. Indeed, prior work has demonstrated that variables predictive of outcome in children of one age group may not be predictive for children in another age group; one example is the utility of GCS in predicting verbal memory function for adolescents aged 13–15 years but not for younger children aged 6–12 years [23]. Similarly, age may account for differences between our findings and those derived from cohorts including a majority of individuals aged 20 years or older [19] or comprised entirely of adults [5]. Drawing definite conclusions from a study population which includes both children and adults with TBI is challenging, as the continually developing brain responds differently to brain injury than the mature brain [14,21]. Furthermore, at least one study has demonstrated that a severity variable (PTA) significantly predicting functional outcome in children with TBI did not predict outcome in adults with TBI [16].

Severity of TBI is another participant-related factor which may have contributed to our unique finding that TFC was the best predictor of functional outcome. Our participants were children with moderate to severe TBI requiring inpatient rehabilitation. Prior studies have recruited participants from regional hospitals with injuries ranging from mild to severe in nature; in fact, more than 50% of the participants studied by McDonald et al. [28] had mild TBI. Inclusion of children with mild to moderate TBI may weaken the predictive value of TFC in comparison to TFC+PTA, given that these children will universally have very short duration to TFC while duration of PTA may be more variable. There is further support from the adult literature of the import of TFC+PTA as a predictor of outcomes after mild TBI [40]; however, it may be that



this predictor loses strength when applied only to children with moderate and severe TBI, as observed in this study.

Our unexpected finding that TFC was the best predictor of outcome may be related to our use of the WeeFIM for outcome measurement. The studies that found that TFC+PTA was a superior predictor variable compared to TFC used differing outcome measures which varied widely in their specificity. Specifically, studies using a less specific outcome measure (Glasgow Outcome Scale score) [19] or more specific measures (individual neuropsychological tests) [28], found that TFC+PTA was clearly superior to TFC in predicting outcome. Interestingly, a study using FIM outcomes (the closest matched outcome variable to WeeFIM for adults with TBI) found that TFC was very closely matched to TFC+PTA with regard to predictive power [5].

The key determinant underlying which measure of severity is most predictive of outcome may be whether the outcome measure is more heavily weighted toward cognitive or motor function. Global outcome scales, including GOS and DRS, can be heavily influenced by cognitive function, and TFC+PTA has been shown to predict these outcomes [19,42,43]. TFC+PTA is also more predictive of cognitive outcome, as measured by neuropsychological testing [28]. In contrast, TFC was previously found to be predictive of functional motor recovery in children [4]. Likewise, in the current and prior [5] work, TFC is strongly related to WeeFIM and FIM, which are weighted toward capturing physical impairments and issues related to burden of care, rather than cognitive functioning. Thus, it may be that the addition of duration of PTA to TFC captures a particularly important marker of neurocognitive recovery, whereas TFC alone is a better predictor of motor outcomes.

The current findings need to be considered in the context of several limitations. This data was collected retrospectively by chart review. As GCS scores were obtained prior to Emergency Room resuscitation/stabilization, they may have overestimated the severity of injury, which may have compromised the performance of GCS in predicting outcomes relative to the other severity variables. TFC was not recorded daily as a yes/no variable during hospitalization, so there may have been some imprecision in its determination. These results may only generalize to patients with injuries severe enough to require inpatient rehabilitation, and other variables known to influence outcome after pediatric TBI, including age, neuroimaging findings, socioeconomic status, and family functioning, were not included in these analyses. Although the WeeFIM is a well established and recognized measure in this population, it does have certain weaknesses including that it lacks the sensitivity of other functional outcome measures. Since the WeeFIM was the only outcome measure used in this study, the results can not be generalized to other types of functioning known to be impacted by TBI.

## 5. Conclusions

The current analyses provide important insight into use of severity variables as predictors of functional outcomes in pediatric TBI. TFC is a standard, practical, and economical measure of injury severity which we have demonstrated to be of superior value in predicting self-care, mobility, cognitive, and overall function at time of discharge from inpatient rehabilitation and subsequent follow-up. This study highlights the importance of accurate and timely assessment and documentation of TFC for both clinical and research purposes given that this clinical severity measure appears to be a useful predictor of functional outcome in children with TBI. Additional research is needed to examine how TFC may be used to determine specific expectations for functional outcomes. As our data suggest that TFC accounts for only part of the variability in WeeFIM outcomes, it is anticipated that future work will be enhanced by incorporation of models accounting for additional variables, such as age at injury and neuroimaging findings.

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**Table 1**

## Patient characteristics

Patient characteristic	Full cohort (n = 120)		Subset with 3 month follow-up data (n = 34)	
	Mean ± SD	Range	Mean ± SD	Range
Age at injury (years)	10.5 ± 4	3–18	11.6 ± 4	3–18
Initial GCS	5.9 ± 3	3–15	6.2 ± 3	3–15
TFC (days)	9.8 ± 11	0–50	7.7 ± 11	0–44
Duration of PTA (days)	17.9 ± 16	0–96	17.2 ± 15	2–68
TFC + PTA (days)	27.7 ± 25	0–142	24.8 ± 25	3–109
Admission Total Self Care DFQ	38.2 ± 25	14–100	42.7 ± 25	14–93
Admission Total Mobility DFQ	35.6 ± 24	14–100	39.0 ± 26	14–100
Admission Total Cognitive DFQ	37.8 ± 21	14–94	48.8 ± 23	14–94
Admission Total WeeFIM DFQ	37.3 ± 21	14–94	43.3 ± 23	14–90
Discharge Total Self Care DFQ	73.7 ± 16	18–106	75.9 ± 16	18–100
Discharge Total Mobility DFQ	71.7 ± 19	20–100	77.9 ± 17	20–100
Discharge Total Cognitive DFQ	68.5 ± 16	29–100	77.0 ± 16	35–100
Discharge Total WeeFIM DFQ	71.7 ± 14	25–96	76.8 ± 14	25–95
3 month follow-up Total Self Care DFQ			95.7 ± 16	14–113
3 month follow-up Total Mobility DFQ			94.5 ± 16	14–100
3 month follow-up Total Cognitive DFQ			91.1 ± 15	43–109
3 month follow-up Total WeeFIM DFQ			94.1 ± 14	22–106

GCS = Glasgow Coma Scale; TFC = Time to Follow Commands; PTA = Post Traumatic Amnesia; TFC + PTA = total duration of impaired consciousness; DFQ = Developmental Functional Quotient (percent of age-appropriate functioning).



**Table 2**

Bivariate correlations between injury severity variables and WeeFIM scores

	Discharge (n = 120)				3 months post-discharge (n = 34)			
	GCS	TFC	PTA	TFC+PTA	GCS	TFC	PTA	TFC+PTA
Self-Care DFQ	0.31 <sup>****</sup>	-0.56 <sup>****</sup>	-0.43 <sup>****</sup>	-0.54 <sup>****</sup>	0.16	-0.53 <sup>****</sup>	-0.25	-0.39 <sup>*</sup>
Mobility DFQ	0.20 <sup>*</sup>	-0.49 <sup>****</sup>	-0.33 <sup>****</sup>	-0.44 <sup>****</sup>	0.19	-0.57 <sup>****</sup>	-0.33	-0.45 <sup>****</sup>
Cognitive DFQ	0.15	-0.33 <sup>****</sup>	-0.21 <sup>*</sup>	-0.29 <sup>**</sup>	0.16	-0.39 <sup>*</sup>	-0.35 <sup>*</sup>	-0.38 <sup>*</sup>
Total DFQ	0.29 <sup>**</sup>	-0.60 <sup>****</sup>	-0.43 <sup>****</sup>	-0.55 <sup>****</sup>	0.19	-0.57 <sup>****</sup>	-0.34	-0.45 <sup>****</sup>

GCS = Glasgow Coma Scale; TFC = Time to Follow Commands; PTA = Post Traumatic Amnesia;

TFC+PTA = total duration of impaired consciousness;

DFQ = Developmental Functional Quotient (percent of age-appropriate functioning).

\*  $p \leq 0.05$

\*\*  $p \leq 0.01$

\*\*\*\*  $p \leq 0.001$ .

**Table 3**  
Hierarchical regression analyses evaluating predictive power of injury severity variables for WeeFIM scores

	Self-care DFQ		Mobility DFQ		Cognitive DFQ		Total DFQ	
	AR <sup>2</sup>	β	R <sup>2</sup>	β	R <sup>2</sup>	β	R <sup>2</sup>	β
<b>Discharge (n = 120)</b>								
Model 1								
GCS	0.09***	0.13	0.04*	0.04	0.02	0.04	0.08**	0.10
TFC	0.24***	-0.44	0.20***	-0.46	0.09***	-0.32	0.28***	-0.52
PTA	0.01	-0.12	0.00	-0.03	0.00	0.01	0.00	-0.08
	Overall model R <sup>2</sup> = 0.34		Overall model R <sup>2</sup> = 0.24		Overall model R <sup>2</sup> = 0.11		Overall model R <sup>2</sup> = 0.37	
Model 2								
GCS	0.09***	0.16	0.04*	0.08	0.02	0.07	0.08**	0.13
TFC+PTA	0.22***	-0.49	0.16***	-0.42	0.06**	-0.26	0.24***	-0.51
	Overall model R <sup>2</sup> = 0.31		Overall model R <sup>2</sup> = 0.20		Overall model R <sup>2</sup> = 0.09		Overall model R <sup>2</sup> = 0.32	
<b>3 mo post-discharge (n = 34)</b>								
Model 1								
GCS	0.03	-0.09	0.04	-0.07	0.03	-0.00	0.04	-0.07
TFC	0.26**	-1.04	0.29***	-0.97	0.12*	-0.31	0.29***	-0.94
PTA	0.11*	0.58	0.07	0.46	0.00	-0.10	0.05	-0.41
	Overall model R <sup>2</sup> = 0.39		Overall model R <sup>2</sup> = 0.39		Overall model R <sup>2</sup> = 0.15		Overall model R <sup>2</sup> = 0.38	
Model 2								
GCS	0.03	0.01	0.04	0.02	0.03	0.01	0.04	0.01
TFC+PTA	0.12*	-0.38	0.17*	-0.44	0.12*	-0.38	0.17*	-0.45
	Overall model R <sup>2</sup> = 0.15		Overall model R <sup>2</sup> = 0.20		Overall model R <sup>2</sup> = 0.15		Overall model R <sup>2</sup> = 0.21	

GCS = Glasgow Coma Scale; TFC = Time to Follow Commands; PTA = Post Traumatic Amnesia;

TFC+PTA = total duration of impaired consciousness;

ΔR<sup>2</sup> = change in R<sup>2</sup> at each step. β = standardized β for each variable once all variables have been entered into the model.

\* p ≤ 0.05

\*\* p ≤ 0.01

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\*\*\*  
 $p \leq 0.001$ .

**Table 4**

Percentage of children with good, moderate, and poor outcomes, based on total WeeFIM DFQ at discharge from inpatient rehabilitation, by length of TFC

TFC	Good outcome (total WeeFIM DFQ $\geq 85$ )	Moderate outcome (total WeeFIM DFQ 70–84)	Poor outcome (total WeeFIM DFQ $< 70$ )
0–2 days ( $n = 41$ )	41%	37%	22%
3–11 days ( $n = 43$ )	12%	49%	40%
12–26 days ( $n = 27$ )	0%	44%	56%
> 26 days ( $n = 9$ )	0%	0%	100%

TFC = Time to follow commands.

DFQ = Developmental Functional Quotient (percentage of age-appropriate functioning).