Communication and psychosocial outcomes 2-years after severe traumatic brain injury: Development of a prognostic model

ABSTRACT

Objective: To examine predictive factors underlying communication and psychosocial outcomes at 2-years post-injury. Prognosis of communication and psychosocial outcomes following severe traumatic brain injury (TBI) is largely unknown yet is relevant for clinical service provision, resource allocation and managing patient and family expectations for recovery. Design: A prospective longitudinal inception design was employed with assessments at 3 months, 6 months, and 2-years. Participants: The cohort included 57 participants with severe TBI. Setting: Subacute and post-acute rehabilitation. Main Outcome Measures: Preinjury/Injury measures included age, gender, education years, GCS & PTA. The 3-month and 6-month data points included speech, language and communication measures across the ICF domains and measures of cognition. The 2-year outcome measures included conversation, perceived communication skills and psychosocial functioning. Predictors were examined using multiple regression. Interventions: Not applicable. Results: The cognitive and communication measures at 6 months significantly predicted conversation measures at 2 years and psychosocial functioning as reported by others at 2 years. At 6 months, 69% of participants presented with a cognitive-communication disorder (FAVRES). The unique variance accounted for by the FAVRES measure was 7% for conversation measures and 9% for psychosocial functioning. Psychosocial functioning at 2 years was also predicted by pre-injury/injury factors and 3-month communication measures. Pre-injury education level was a unique predictor accounting for 17% of the variance and processing speed/memory at 3 months uniquely accounted for 14% of the variance. Conclusion: Cognitive-communication skills at 6 months are a potent predictor of persisting communication challenges and poor psychosocial outcomes up to 2 years after a severe TBI.

Findings emphasise the importance of addressing modifiable cognitive and communication outcomes variables during the first 2 years following severe TBI to maximise functional patient outcomes.

Key words: Traumatic brain injury, prognosis, communication, cognition, outcomes.

Abbreviations: Boston Naming Test-2 (BNT-2), Frenchay Dysarthria Assessment-2 (FDA-2), Functional Assessment of Verbal Reasoning and Executive Strategies (FAVRES), Glasgow Coma Scale (GCS), La Trobe Communication Questionnaire (LCQ), Measure of Support in Conversation (MSC), Measure of Participation in Conversation (MPC), Post-Traumatic Amnesia (PTA), Sydney Psychosocial Reintegration Scale (SPRS), Traumatic Brain Injury (TBI), Western Aphasia Battery-Revised (WAB-R), World Health Organization – International Classification of Functioning (WHO-ICF).

Traumatic brain injury (TBI) is a major cause of death, disability, and economic burden[1,2]. The estimated global prevalence of TBI is between 55.5-69 million[1-3] and global annual costs are projected at $US400 billion[4]. Longer-term health outcomes following severe TBI are concerning with significant reports of disability, impacts on daily life, dissatisfaction with life and disengagement with work and community[5]. Factors associated with long-term health outcomes are numerous; however, duration of post-traumatic amnesia (PTA), as a proxy of injury severity, is one of the strongest known predictors of global outcomes[6], return to productivity[7,8] and treatment costs[9]. Multiple neuropsychological variables are also implicated in the recovery process from a TBI[10]. It is evident that enduring global functional challenges are experienced by adults with TBI, and that injury severity and the cognitive neuropsychological profile of the individual are useful predictors of global outcomes. The contribution of predictors specifically to communication and psychosocial outcomes after TBI is not clearly established.

Communication characteristics across the ICF

Communication problems from TBI can be observed across the World Health Organization – International Classification of Functioning (WHO-ICF) domains of impairment, activity/participation, and environmental functioning. Communication performance after a traumatic brain injury can vary according to a range of factors such as "…communication partners, environment, communication demands, communication priorities, fatigue, physical and sensory issues (e.g., vision, hearing), psychosocial variables, behavioral dyscontrol, emotional variables, and other personal factors"[11]. Cognitive-communication disorders are the most common type of communication difficulties observed after a traumatic brain injury, identified in up to 85 percent of individuals during early recovery from a severe traumatic brain injury[12]. A cognitive-communication disorder is defined as any communication difficulty that results from underlying cognitive impairments with attention, memory, executive function and social cognition[11,14,15]. Neurologically, these cognitive impairments arise predominantly from fronto-temporal pathology, axonal shearing and white matter connectivity[4,16]. Communication disorders may also include disorders of language (aphasia), anomia (word-retrieval impairment) and/or motor speech (dysarthria)[17]. Such challenges impact key functional and participation outcomes for individuals with TBI including returning to work, independence and participation in social and leisure activities[18,19]. There is established consensus that global outcome measures fail to adequately capture communication performance across these range of impairments and there is need for inclusion of more nuanced measures in prognostic research[20].

Communication problems commonly impact everyday discourse activities such as having a conversation and consequently affect participation in everyday interactions. For example, people with a TBI may have difficulty initiating conversation, disinhibiting socially inappropriate or contributing to a conversation, Unsurprisingly, conversations of people with

TBI may be perceived as effortful, uninteresting, inappropriate and unrewarding[21]. This can be attributed to the inherent complexity of social interaction and TBI disrupting the interaction between cognition, communication, emotional, physical and personal factors, self-regulation and communication competence[21-23]. The communication environment which includes communication partners can also play a crucial role in the success of post-injury interactions[24]. Many people with severe TBI have chronic cognitive-communication problems that contribute to poor psychosocial outcomes such as breakdown in family relationship[25], loss of friends[26], a failure to return to work and social isolation[27].

Modelling communication outcomes after TBI

Whilst a handful of studies have examined communication outcomes there is insufficient evidence available for prognosis of communication outcomes after severe TBI due to limitations in existing study designs. For example, age at time of injury and Functional Independence Measure -Motor scores were identified as predictors of communication items in a sample of 292 patients with mild-severe TBI[28]. In other research, education and TBI severity were identified as the most significant predictive factors of language outcomes in a cohort of 348 acute patients with mild-severe TBI[29]. The core limitations of these existing studies include insufficient sensitivity to the nuances of communication with use of tools such as the Functional Independence Measure, a narrow focus on the impairment domain of the WHO-ICF and failure to extend beyond the acute period of recovery. Also, there is a need to consider a wider range of variables in multivariate analysis including pre-injury/injury and post-injury variables which have not been included in existing prognostic modelling.

Modelling psychosocial outcomes with inclusion of communication variables

Various outcome measures have been utilised in prognostic models for TBI[30] such as the Functional Independence Measure[31] and the Glasgow Outcome Scale Extended[32]. Whilst these core outcome measures are highly informative, they are not sensitive to detecting subtle cognitive-communication deficits. Hence, the addition of measures with improved sensitivity to cognitive-communication[33] and nuanced psychosocial outcomes following TBI is warranted. Participation -level outcomes[34] and return to work or driving outcomes have also been explored in prognostic modelling and shown to be informative for capturing long-term psychosocial outcomes[35]. Injury severity has consistently shown to be associated with psychosocial outcomes[35] but there is a need to further understand factors influencing psychosocial outcomes following severe TBI. There is a paucity of models including pre-injury and injury variables but also sensitive measures of communication. Such nuanced communication measures at 6 months, in addition to age, years of education and aphasia have been shown to predict psychosocial outcomes at 1 year post-injury[18] but it is unknown if these findings reflect outcomes beyond the first year.

Current Study & Aims

The present study was motivated by the need for prognostic models of communication and psychosocial outcomes for TBI that incorporate prospective, longitudinal methodologies extending beyond acute recovery and include nuanced communication measures across the WHO-ICF domains. Such models are required to inform delivery and planning of rehabilitation services. Hence, the primary aim of this study was to develop prognostic models for communication and psychosocial outcomes at 2-years post severe TBI including pre-injury, injury and post-injury variables and communication variables that extend across the WHO-ICF domains.

METHODS

Study design

A prospective longitudinal cohort design was selected to meet the aims of the study. Data were collected at 3 months post-injury, 6 months post-injury and 2-years post-injury.

Participants

Participants were recruited from three metropolitan Brain Injury Rehabilitation Units in [Redacted for review]. Participants were included in the study if they were aged between 16 and 70 years of age, had sustained a severe TBI (Glasgow Coma Scale (GCS) score ≤ 8 and/or post-traumatic amnesia (PTA) duration > 24 hours)[36], were no longer in a state of PTA, were medically stable, and spoke English as a language of daily use. Exclusion criteria included history of a previous neurological illness (e.g., dementia) or TBI or if the clinical team deemed the patient unsuitable for the project (medical reasons n = 1; other reason n = 1). Recruitment was conducted over a 21-month period between June 2011 and March 2013. Participants were required to identify a familiar communication partner to participate in selected components of the assessment battery. A flow diagram of the recruitment and retention process is presented in Figure 1.

Figure 1 about here

Measures

Pre-injury/injury predictor measures

Three pre-injury measures were examined in this study: age, gender, and years of education. Measures were initially obtained from patient report and verified with the patient medical record. The lowest GCS and PTA duration were captured as proxy measures of injury severity.

Post-injury predictor measures (3 and 6 months)

The post-injury measures comprised a selection of cognitive tests, and speech/language/communication measures. Three cognitive domains were evaluated: (i) information processing speed using the Symbol Digit Modalities Test[37], (ii) verbal and visual memory using the Hopkins Verbal Learning Test[38], and the Brief Visuospatial Memory Test[39] respectively; and (iii) executive functioning, using three subtests from the

Neuropsychological Assessment Battery[40]. For data analysis, the processing speed and memory domains were combined into a single index.

The speech/language/communication measures spanned multiple ICF domains. Impairments were evaluated with three tests: Western Aphasia Battery-Revised (WAB-R)[41], the Boston Naming Test-2 (BNT-2)[42], and Frenchay Dysarthria Assessment-2 (FDA-2)[43]. Communication at the activity level was evaluated with the Functional Assessment of Verbal Reasoning and Executive Strategies (FAVRES)[44].

Post-injury communication outcome measures (2-years)

Outcome measures collected at 2-years post-injury included two communication measures that capture participation and environmental domains of functioning: the La Trobe Communication Questionnaire–other report (LCQ-other)[45] and the Adapted Kagan Rating Scales which include two components; conversation participation (Measure of Participation in Conversation, MPC) and conversation support (Measure of Support in Conversation, MSC)[46]. The MPC and MSC are calculated from a 10-minute unstructured conversation sample between the individual with TBI and a familiar communication partner.

Post-injury outcome psychosocial measures (2-years).

The Sydney Psychosocial Reintegration Scale – 2 other report[47] was selected as the psychosocial outcome measure at 2 years.

An overview of the measures is provided in Table 1. All measures were delivered using standardised administration and scoring guidelines and have published evidence of adequate test reliability.

Table 1 about here

Procedure

Participants were assessed at 3 months (if enrolled) and/or six months, and two-years post injury. Assessments were conducted in entirety by one of two registered speech pathologists (EE & BK) and one of the two clinical neuropsychologist recruited to the project. All assessors had experience in standardised test administration and interviewing of people with TBI. Where possible, the same assessor and order of task administration was used for each participant at each time point. Assessors were unblinded to the assessment time point. The administration of items across the time points is indicated in Table 1. To reduce the burden of testing, the WAB-R and FDA-2 were only readministered from 3 to 6 months if performance at 3 months was impaired. The FAVRES (cognitive-communication measure) was initially included at 3 months but was not well tolerated by a pilot group of participants. Subsequently, this test was removed from the 3-month time point.

Participant characteristics

Forty-six males and 11 females aged between 16-66 with a median age of 33 years (35.25 +/- 13.1) participated in this study. Demographic data was available for 52 out of 57 communication partners who completed the proxy measures. The communication partners were predominantly female n = 43 with a mean age of 46.67 years. Relationship to the participant was mostly parents (n=24) followed by partners (n=16) then children (n=5), siblings (n=4) and other relatives (n=3). Table 2 presents an overview of descriptive data for the pre-injury, post-injury and outcome variables.

Insert Table 2 about here

Data Analysis

Initial screening of continuous predictor variables with the Kolmogorov-Smirnov indicated nonparametric data. Assumption testing was completed for the regressions. A principal components analysis (PCA) with varimax rotation was conducted on the initial 3-month cognition variables. This was done to minimise multicollinearity and to reduce the subject to variable ratio. A two-component solution was deemed to be the most interpretable. This solution accounted for 69.55% of variance in the data. The final solution with seven cognition variables accounted for 72.75% of variance in the data. The components were named Processing/Memory (component 1) and Executive Functions (component 2). The variables defining each component with loadings and Cronbach's α values is presented in Appendix 1. The correlation between the two components was r =.58.

The research questions, investigating predictive factors underlying communication recovery and psychosocial outcomes, was addressed through multiple regression design with three blocks as indicated in Table 3 and Spearman correlation analyses between variables as indicated in Table 4. A two-tailed test of significance with an alpha level of .05 was applied to the analysis. All significance tests used adjusted p value based on 1,000 bias-corrected bootstrapped samples.

Rigour

Design and reporting of this study was guided by the Tripod statement[48].

Ethics

This project was approved by the Australian National Human Research Ethics Committee. Approval was also obtained from relevant health service and university Human Research Ethics Committees, with informed consent or assent obtained from the person with TBI and/or guardian.

RESULTS

Predictors

Prediction models are presented in Table 3. Of the three communication outcomes measured at 2 years, only the 6-month variables significantly predicted one outcome, which was conversation participation (Kagan MPC). (R^2= .678, p=.025). The cognitive-communication measure (FAVRES) uniquely accounted for 7% of the variance in this model (β = .542, SE=.006, p=.171). Dysarthria also accounted for 7.7% of the variance in this model (β = .329, SE=.010, p=.153). The remaining regression models for 2-year communication outcome measures were not significant.

Psychosocial outcomes (SPRS-2-other) at 2 years were significantly predicted by pre-injury/injury variables (R^2= .334, p=.013), 3-month variables (R^2= .395, p=.013) and 6 month variables (R^2= .498, p=.006). Pre-injury education level uniquely accounted for 17.3% of the variance in the first block. The information processing speed/memory index at 3 months uniquely predicted 13.8% of the variance in the second block. The cognitive-communication measure (FAVRES) uniquely accounted for 9.2% of the variance in the final block and represents a large effect size however it did not reach significance due to the small sample size.

Table 3 about here

Correlations

Correlation coefficients between all variables and the 2-year outcomes are provided in Table 4. Significant correlation coefficients are detailed below. Correlation coefficients are positive unless stated otherwise.

Demographic variables

Longer PTA duration was associated with reduced psychosocial outcome (SPRS-2-other) (R_S =-.432, p =.005). The GCS and the Kagan MSC (conversation support) (R_S =-.406, p =.049) had a moderate negative correlation. Education years had a weak correlation with SPRS-2-other (other-reported psychosocial outcomes) (R_S =.378, p =.016).

3 months

The information processing speed/memory measure was moderately correlated with psychosocial outcomes at 2 years (SPRS-2-other) (R_S =.570, p=.000). Aphasia also had a moderate correlation with SPRS-2-other (R_S =.435, p=.013). There was also a moderate correlation between the information processing speed/memory index and the conversation participation measure (Kagan MPC) (R_S =.538, p=.012). The executive function index was weakly correlated with the SPRS-2-other (other-reported psychosocial outcomes) (R_S =.396, p=.022).

6 months

A strong correlation was identified between the cognitive-communication measure (FAVRES) and psychosocial outcomes (SPRS-2-other) (R_S =.706, p=.000) and conversation participation (Kagan MPC) (R_S =.707, p=.001) at 2 years. The cognitive-communication measure (FAVRES) was also moderately negatively correlated with the LCQ-other (other-reported perceived communication) (R_S =-.459, p=.008).

The information processing speed/memory index was moderately negatively correlated with perceived communication (LCQ other) (R_S =-.507, p=.002) and moderately positively correlated with the psychosocial outcome measure (SPRS-2-other) (R_S =.546, p=.001). The executive function index was moderately correlated with conversation participation (Kagan MPC) (R_S =.456, p=.043) and weakly correlated with the perceived communication (LCQ-other) (R_S =.384, p=.021).

Aphasia was moderately correlated with psychosocial outcomes (SPRS-2-other) (R_S =.497, p=.001) and conversation participation (Kagan MPC) (R_S =.663, p=.001). Dysarthria was moderately correlated with conversation participation (Kagan MPC) (R_S =.556, p=.006) and weakly correlated with the psychosocial outcomes (SPRS-2-other) (R_S =.334, p=.044).

Table 4 about here

DISCUSSION

This is the first study to explore predictors of communication and psychosocial outcomes following severe TBI across the WHO-ICF domains of impairment, activity/participation and environmental domains. Overall, predicting communication recovery and psychosocial outcomes after severe TBI is a complex phenomenon that is influenced by an individual's premorbid functioning, the nature of their injury and early communication and neuropsychological function.

Factors that predict communication recovery at two years post injury

At 3 months post-injury, no communication measures and only one neuropsychological domain, the information and processing speed/memory index, predicted communication outcomes. This finding was unsurprising due to the many known factors that can potentially affect early communication performance[11] including the possible influence of medications, fatigue and generalized confusion that are common in the early recovery phase. At 3 months many participants were also demonstrating resolving language and motor speech issues and heterogeneity of communication outcomes is well reported in this population, which may also account for varied findings[49]. Of note, the cognitive-communication measure (FAVRES) was unable to be effectively administered to participants at 3 months. These are important findings for clinicians who frequently receive requests to provide prognostic information to individuals with TBI and their caregivers. Early cognitive performance paired with consideration of early recovery factors such as generalised confusion, fatigue, and the ability to tolerate cognitive-communication assessment, may be indicative of later communication recovery. On the other hand, six months post injury was a critical timeframe for predicting participants' communication outcomes. The six-month predictive findings may also incorporate the effect of including the cognitive communication measure (FAVRES). A stronger cognitive-communication (FAVRES) profile at 6 months predicted positive participation in conversation (Kagan-MPC). This tool appears to be a potent assessment of potential communication outcomes when administered at 6 months post injury and highlights the importance of communication assessment at the level of activity and participation. Future directions for research could include further validation and reliability testing of sensitive cognitive-communication measures that can be sufficiently tolerated during early recovery.

Factors that predict psychosocial outcomes at two years post injury

Communication measures at 6 months predicted 2-year psychosocial outcomes in this study. Unique predictors included pre-injury education level, PTA duration and information processing speed/memory (3 months). These findings are aligned with existing evidence around the influence of pre-injury education, injury severity variables and early neuropsychological variables on outcomes following TBI [10]. A novel finding of this study was that communication measures at 6 months, including a measure of cognitive-communication (FAVRES) predicted psychosocial outcomes, such as maintaining social relationships at 2-years (LCQ-other). This was the first study to include communication measures across the ICF into a predictive outcome model. Incorporating the activity and participation-level cognitive-communication measure (FAVRES) in the multiple regression model predicted the 2-year psychosocial outcomes which reinforces the value of assessing and supporting communication at the level of activity and participation.

Clinicians should be cognizant that early cognitive performance paired with consideration of early recovery factors may provide an indication on potential prognosis of communication. The clinical implications for these findings could include recommending services for cognitive-communication difficulties during early recovery and advocating for maintenance of services for cognitive-communication disorders beyond 6 months post-injury. Key clinical tools could include the Functional Assessment of Verbal Reasoning and Executive Strategies to inform service recommendations, and conversation as a core communication outcome measure. For more in-depth case descriptions on the topic of communication recovery, the reader is directed to other publications arising from this dataset[50-55].

Study Limitations & Future Research

This is the first study to provide a comprehensive profile of communication recovery at the impairment, activity/participation and environment levels 2-years after severe TBI. Limitations included the sample size and low subject to variable ratio which was impacted by the challenges of recruiting and retaining adults with severe TBI for rigorous communication assessment. Hence, the results of this paper should be interpreted cautiously and future research with large sample sizes is warranted to confirm these findings. The study excluded non-English speaking people, people with mental health or substance abuse issues and people who were deemed inappropriate by the clinical teams . These exclusions may have influenced findings by removing a small number of potential participants who may have had poor communication outcomes. The assessors were aware of the post-injury time point, but this potential bias was reduced through standardized administration and scoring procedures. The assessors were aware of the post-injury time point, but this potential bias was reduced through standardized administration and scoring procedures. Future research is needed to further examine predictors of communication recovery in larger samples and to explore the effects of early intervention upon long term outcomes. Considerations for future research include exploring the sensitivity and acceptability of measures during early recovery. Researchers might consider screening tools (e.g. WAB-R screening) or shortened/adapted versions of the measures selected. Capturing additional relevant variables such as fatigue and social cognition measures (e.g. The Awareness of Social Inference Test – Short[56]) may also add value to prognostic research in this field.

Conclusions

Outcomes from this study demonstrate a complex web of factors underpinning recovery of communication skills and return to premorbid levels of vocational, leisure and social participation and independence. Our study emphasises the importance of timely clinical services for cognitive-communication difficulties during early recovery from TBI . Moreover, ongoing recovery of cognitive-communication was identified at six months post injury and services should be maintained to support persisting cognitive-communication challenges consistent with existing evidence-based practice recommendations[11]. Our findings suggest that the FAVRES provides a sensitive and powerful contribution to a speech pathologist's diagnostic tool kit. Adopting an activity level and more participatory approach to verbal reasoning and cognitive-communication may address a broad range of rehabilitation goals for people with severe TBI. Findings also suggest that injury variables and performance in everyday communication tasks, such as conversation should not be understated as relevant to communication outcomes.

Transparency, Rigor and Reproducibility Summary

The study design was a longitudinal prospective inception cohort guided by the TRIPOD Checklist. Sample size was 57 participants with severe Traumatic Brain Injury based on optimal sample size for multiple regression with 5 predictors, an alpha of .05, power set at 0.8 and a medium effect size R^2=.25. Principle components analysis with a varimax rotation was used to minimise multicollinearity and to improve the subject:variable ratio. All significance tests used adjusted p values based on 1,000 bias-corrected bootstrapped samples.

Participants were assessed at 3 months, 6 months and 2 years post-injury by qualified health professionals. Conversation measures at 2 years were significantly predicted by cognitive and communication measures at 6 months (R^2=.678; p=.025). Psychosocial outcomes at 2 years were significantly predicted by pre-injury/injury factors (R^2=.334; p=.013), 3 month cognitive and communication variables (R^2=.395; p=.009) and 6 month cognitive and communication measures (R^2=.498; p=.006). The FAVRES cognitive-communication measure uniquely accounted for 7% of the variance in conversation and 9% of the variance in psychosocial outcomes. Other unique predictors included pre-injury education level and processing speed/memory which respectively accounted for 17% and 14% of the variance in psychosocial outcomes. Data from this study is available in the TalkBank repository and can be accessed at https://tbi.talkbank.org.

Competing Interests: The authors declare no conflicts of interest.

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FIGURES

Figure 1. Referral, recruitment, and retention flowchart