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Functional Outcome Trajectories following Inpatient Rehabilitation for TBI in the United States: A NIDILRR TBIMS and CDC Interagency Collaboration

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Abstract

OBJECTIVE: To describe trajectories of functioning up to 5 years after traumatic brain injury (TBI) that required inpatient rehabilitation in the United States using individual growth curve models conditioned on factors associated with variability in functioning and independence over time.

DESIGN: Secondary analysis of population-weighted data from a multicenter longitudinal cohort study.

SETTING: Acute inpatient rehabilitation facilities.

PARTICIPANTS: 4,624 individuals 16 years and older with a primary diagnosis of TBI.

MAIN OUTCOME MEASURES: Ratings of global disability and supervision needs as reported by participants or proxy during follow-up telephone interviews at 1, 2, and 5 years post-injury.

CONFLICTS OF INTEREST: None.

DISCLOSURES: The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the Centers for Disease Control and Prevention.

RESULTS: Many TBI survivors experience functional improvement through 1 and 2 years post-injury, followed by a decline in functioning and decreased independence by 5 years. However, there was considerable heterogeneity in outcomes across individuals. Factors such as older age, non-white race, lower pre-injury productivity, public payer source, longer length of inpatient rehabilitation stay, and lower discharge functional status were found to negatively impact trajectories of change over time.

CONCLUSIONS: These findings can inform the content, timing, and target recipients of interventions designed to maximize functional independence after TBI.

Keywords

Traumatic brain injury; rehabilitation; outcomes; disability; independence; longitudinal data analysis

INTRODUCTION

It is estimated that well over 5.3 million people in the United States (U.S.) are living with disability related to Traumatic Brain Injury (TBI), making TBI one of the major causes of long-term disability in adults.[1–3] National estimates of outcomes in the first 5 years after a TBI requiring acute rehabilitation indicate that approximately 1 in 5 adolescents and adults have died and 3 in 10 have declined from the level of functioning attained 1–2 years after their injuries.[4] Five years after a TBI requiring inpatient rehabilitation, a substantial proportion of survivors need assistance or supervision in motor (30%) or cognitive (36%) functioning; 33% require supervision overnight and for at least part of their waking hours; and 57% are unable to resume half of their preinjury activities.[4] While some outcomes at 5 years were strongly influenced by age (e.g., mortality, functional independence and need for supervision, and rates of institutionalization and rehospitalization), important outcomes including worsened psychological status, overall disability and decline from previously attained levels of function were distributed across all age groups. These findings underscore the considerable impact of TBI on long-term outcomes, but also suggest that a variety of person and injury factors beyond age can influence an individual's functional trajectory.

Functional outcome following TBI is commonly defined by two factors: the degree of limitations or disability experienced by the individual with TBI, and the amount of supervision that needs to be provided for the individual with TBI. The Disability Rating Scale (DRS) is a reliable measure of global functional limitations after moderate to severe TBI.[5–8] The amount and type of supervision needed by individuals with disabilities can vary greatly. Although supervision received can depend on the availability of caregivers, post-TBI supervision needs are reliably measured by the Supervision Rating Scale (SRS).[9,10]

Both person and injury-related factors have been linked to functional outcome after TBI. Personal or pre-injury factors commonly associated with functional outcomes include demographics (age at injury,[11,12] sex,[13] and insurance status[14]) as well as level of education and employment at the time of injury.[11,15,16] In general, younger age at injury, having private insurance, and higher levels of education and employment are associated with lower levels of disability. Injury-related factors such as injury severity determined by Glasgow

Coma Scale (GCS), mechanism of injury, imaging findings, and length of post traumatic amnesia (PTA) also contribute to functional outcomes.[11,17,18] Status at hospital discharge, indicated by DRS and functional outcome measures, also shows a relationship to later outcomes.[19,20] Neuroanatomic features of TBI that have been associated with outcome include brain asymmetry,[21] herniation, intracranial hemorrhage,[22] white matter axonal shearing, thalamic injury,[23] and post-traumatic hydrocephalus.[24,25] The effects of discrete neuroanatomic features on outcome have received considerable attention as indices of intracranial injury are increasingly incorporated into predictive models.[17,26,27]

Given the breadth of factors that impact long-term outcomes after TBI, it is not surprising that outcomes can differ tremendously across individuals. Although numerous studies have evaluated the relationships between pre-injury and injury-related factors to functional outcomes, few have considered longer-term outcomes at the individual level using models that allow inclusion of multiple covariates. The purpose of this study was to use individual growth curve (IGC) analyses to examine factors that impact the trajectory of functional outcomes (DRS and SRS) over time (1, 2, and 5 years post-injury) after complicated mild to severe traumatic brain injury (TBI) using the TBI Model Systems (TBIMS) National Database (NDB) weighted to reflect the population of individuals in the United States (US) who receive inpatient rehabilitation for TBI.

METHODS

Sample

Participants were consecutive admissions who qualified for and were prospectively enrolled in the TBIMS multi-site longitudinal national database (in existence since 1988 funded by the National Institute on Disability, Independent Living, and Rehabilitation Research). Eligibility requires the participant to have sustained a TBI; be age 16 years or older at the time of injury, received medical care in a TBIMS-affiliated trauma center (one that is a part of the health care system of a TBIMS center) within 72 hours of injury; have transferred directly to an affiliated inpatient TBI rehabilitation program; and provided informed consent for him/herself or by legal proxy. Participants in the TBIMS have sustained a complicated mild, moderate or severe TBI as defined by at least one of the following: Glasgow Coma Scale score <13 on emergency department presentation, loss of consciousness >30 minutes, post-traumatic amnesia >24 hours, or trauma-related intracranial abnormality on neuroimaging. During inpatient rehabilitation, data are collected through interview and chart review. Following rehabilitation discharge, participants are followed prospectively (1, 2, and 5 years post-injury and every 5 years thereafter) using a standardized follow-up assessment protocol. The current study uses data gathered at 1, 2, and 5 years post-injury. Further information about the TBIMS NDB variables and procedures is available at www.tbindsc.org. All TBIMS sites have ongoing approvals by their local institutional review board.

Outcome Measures

Supervision Rating Scale (SRS): The SRS measures the level of supervision received through a structured interview with a caregiver or person with brain injury. Using a 13-point ordinal scale the results are grouped into five categories: Independent, Overnight Supervision, Part-Time Supervision, Full-Time Indirect Supervision, and Full-Time Direct Supervision. The SRS[10,28] is widely used in TBI populations and has been shown to have sufficient reliability and validity. The TBIMS collects the SRS beginning at year 1 post-injury, and at each follow up thereafter. For purposes of this study, SRS was dichotomized as Independent versus Not Independent (e.g., requiring any part-time, full time, or overnight supervision); the probability of being Independent was modeled.

Disability Rating Scale (DRS): The DRS is an 8-item scale designed to measure recovery from "coma to community." As such, the items assess arousal, responsiveness, cognitive ability to perform self-care, independent living, and employability. Possible total DRS scores range from 0 (no disability) to 29 (vegetative state). This measure has been widely used in brain injury research. In post-acute samples, the DRS may have floor effects with a large number of individuals scoring low (minimal disability).[29] However, the DRS has shown sensitivity to change over time following TBI.[6–8] The TBIMS collects DRS at inpatient rehabilitation admission and discharge, as well as at each follow-up (1, 2, 5, and every 5 years thereafter post-injury).

Covariates

Covariates were selected *a priori* based on previously-demonstrated relationships with the outcomes of interest and/or change in outcomes over time. Age,[30–34] sex,[34,35] pre-injury education,[16,32] race,[31] rehabilitation length of stay (LOS),[36] findings on acute computed tomography (CT) scan,[37] Functional Independence Measure (FIM™), and DRS performance during the rehabilitation stay,[31,32] are all associated with functional outcome and recovery. Similarly, several psychosocial factors such as pre-injury marital status, pre-injury living situation, pre-injury employment, pre-injury substance use, and rehabilitation payer source have been associated with TBI outcomes.[30,34,38] We considered each of these variables as covariates in the current study.

Age at injury was modeled as a continuous variable, sex was coded as male or female, and pre-injury level of education was measured in years and coded categorically as greater than high school or less than or equal to high school (12 years of education). Race was collected in the TBIMS NDB based on self-report and is coded here as White or Not White. Rehabilitation LOS was computed as the total number of days between inpatient rehabilitation admission and discharge. We considered several indices of computed tomography (CT) scan findings; these included extent of intracranial compression, punctate/petechial hemorrhages, and intraventricular hemorrhage, each coded as present or absent. The FIM™ is an 18-item measure of functional independence,[39] and the current study uses data collected at rehabilitation discharge on both the 13-item FIM™ motor and 5-item FIM™ cognitive subscales. Each item in these subscales is scored using a rating scale that ranges from 1 (total assistance) to 7 (complete independence), yielding a score range of 13 to 91 for the motor FIM™ and 5 to 35 for the cognitive FIM™. We also considered DRS scores at rehabilitation discharge. Pre-injury marital status was coded as Married or Not Married; pre-injury living situation was coded as Alone or Cohabitating, pre-injury employment was coded as Productive (competitively employed, full- or part-time student, retired) or Not Productive (all other categories). Pre-injury substance abuse was coded as Yes/No, and was defined as: any illicit/non-prescription drug use in the year prior to injury, OR problematic alcohol use in the month prior to injury (defined as drinking >14 drinks/week for men OR drinking >7 drinks/week for women OR > 5 drinks/occasion for both men and women). Rehabilitation payer source was categorized as Medicare/Medicaid or Other (which included commercial and private insurance coverage and self-pay).

An interactive tool was developed to allow a user to manipulate values on each covariate to observe the resultant changes in trajectory shape. Manipulating only one covariate while holding others constant allows observation of how that variable impacts the trajectory shape; manipulating multiple covariates allows a user to visualize the cumulative influence of multiple characteristics on the shape of the outcome trajectory. The tool is not intended to be used for prognostication for individuals, but instead to illustrate the complex relationships between covariates and outcome trajectories over time based on data available in the nationally weighted NDB.

Estimation of Sampling Weights

There were 9,679 subjects with data available in the NDB (data freeze September 30, 2016) who were at least 1 year post-injury. Annual sampling weights were available for 7,178 of these subjects admitted to rehabilitation between 1/1/2002 and 12/31/2010. There were 6,429 subjects with complete covariate data (89.8%).

Missing outcome data was imputed for 2,272 subjects missing exactly one year of DRS data and for 1,017 subjects missing exactly one year of SRS data. There were 4,653 subjects with complete DRS data and 4,911 subjects with complete SRS data after imputation. We further limited the sample to those individuals who had complete data on *both* of the primary outcomes in the current study; there were then 4,624 (71.92%) subjects with complete DRS and SRS outcome data, 1,143 (17.78%) with incomplete DRS and SRS outcome data, and 662 subjects (10.3%) who had died by their 5 year interview. See Figure 1 for a summary of sample selection and imputation methods.

Sampling weights were generated to ensure that study results were more representative of *all* (the population of) those with moderate to severe TBI who received inpatient rehabilitation in the US. Annual sampling weights were estimated using iterative proportional fitting (IPF) methods for each year of data to account for change in population characteristics over time. Known population proportions were obtained annually from data for 2002 to 2010 on late teens and adolescents over the age of 16 who were admitted to inpatient rehabilitation with a primary diagnosis of TBI and were submitted to one of two central data repositories that serve as intermediaries for the Center for Medicare and Medicaid Services, the Uniform Data Systems for Medical Rehabilitation (UDSMR, which uses the UDS-PRO® software system) and the American Medical Rehabilitation Providers Association database (eRehabData). These data systems include a minimum of 92% of all civilian rehabilitation facilities in the US (in 2007, for example, approximately 74% and 18% of inpatient rehabilitation facilities submitted data to UDS-PRO® and eRehabData, respectively),[40] which reflects an even larger percentage of patients as UDS-PRO and eRehabData subscribers include the largest inpatient rehabilitation facilities in the nation. Parameters used to estimate weights are described in detail elsewhere.[40–42] A recent study by Pretz *et al.* (2014) demonstrated the utility of this methodology to weight the TBIMS NDB.[43] The weights for cases with complete covariate and outcome data were then adjusted to account for non-responder bias using propensity score methodology to ensure the weighted analytic sample remained representative of the population.[44]

Data Analysis

The weighted sample of 4,624 subjects with complete outcome and covariate data and alive at 5 years post-injury was used for all data analyses. Individual growth curves were fit using random coefficient models in order to assess the relationship between each covariate and the trajectory of outcomes over time. A linear mixed-effects random coefficients model was used to model DRS and a generalized linear mixed-effects model with a logit link function was used to model SRS (i.e., the probability of "independence"). For the DRS model, subject-specific random intercepts, linear slopes, and quadratic slopes were fit for all subjects assuming an unstructured covariance pattern among the random effects. Subject-specific random quadratic slopes were not included in the SRS model as this typically leads to problems with model convergence and significant variation in subjects for higher-order terms are rarely seen in practice when modeling a dichotomous outcome. Initially, the relationship between time and outcome was assessed without adjusting for any covariates to determine the appropriate shape of the trajectory. Mean, linear, and quadratic models were compared and the model with the best fit was selected. Next, all covariates and their interactions with time (linear and quadratic, depending on the shape assumed) were added to the model to fit a separate trajectory pattern for each level of the covariates. One benefit of the IGC approach to longitudinal modeling of these data is that individual level interpretations and comparisons of the DRS and SRS trajectories are possible.[43,45] Individual level comparisons are summarized using differences (SRS) and odds ratios (SRS) for comparing two individuals who differ in terms of one characteristic only, and are equal on all other characteristics. As varying one characteristic is just one possible way to compare individuals, a user friendly interactive tool was developed to graphically demonstrate how varying one or more characteristics between individuals is expected to change outcome trajectories. SAS v.9.4[46] was used for all statistical analyses and Excel 2010 was used to create the interactive tool.

RESULTS

Sample Characteristics

The distributional characteristics for the sample are summarized in Table 1 (continuous variables) and Table 2 (categorical variables). As reported in our prior work, the NDB sample is younger and more racially diverse than the larger population of individuals in the US who receive inpatient rehabilitation for TBI.[41,42] Accordingly, the weighted sample used in the current study is older and more diverse than the unweighted sample, reflecting its improved representativeness of the larger population. Consistent with the older age of the population, the weighted sample contains a greater proportion of individuals who are female, white, married, living alone, not engaging in substance abuse, and having Medicare and Medicaid as their primary rehabilitation payer source as compared to the unweighted sample (see Table 2). The weighted sample also has a shorter rehabilitation LOS, while the samples are similar in discharge functional status.

Unadjusted Functional Trajectories

The mean DRS score and the percent of subjects who were classified as independent on the SRS are summarized over time in Table 3 for the weighted sample. For both outcomes, we observe group-level trend of improvement between Years 1 and 2 (as reflected by decreasing DRS scores and a greater proportion of the sample being categorized as Independent on the SRS), followed by decline between Years 2 and 5 (as reflected by increasing DRS scores and a lower proportion of the sample being categorized as Independent on the SRS).

Preliminary analyses indicated that both outcomes had a quadratic relationship with time and fit significantly better than a linear or constant relationship. The average trajectory over time (red) is shown in Figure 2 (DRS) and Figure 3 (SRS) along with the subject specific trajectories (black). As seen in these figures, there is a substantial amount of variation among subjects in both DRS and SRS trajectories.

Adjusted Functional Trajectories

The set of covariates and their interactions with the quadratic trajectory were then added to the models to assess the multivariable effect of these covariates on the DRS and SRS trajectories in terms of both mean shifts in the trajectory (up and down) and changes in general shape of the trajectory. Parameter estimates for the multivariable DRS and SRS trajectory models are summarized in Supplemental Tables 1 and 2.

The multivariable model for DRS indicated that positive mean shifts in the DRS trajectory (worse functioning) were associated with older age, non-white race/ethnicity, not being productive prior to injury, lower levels of education, having Medicare or Medicaid as a payer source, lower FIM motor and cognitive discharge scores, higher DRS discharge scores, and longer rehabilitation stays. Changes in the shape of the DRS trajectory (i.e., the direction, extent and/or rate of change) were associated with payer source, rehabilitation length of stay, and DRS discharge scores.

The multivariable model for SRS indicated that negative mean shifts in the SRS trajectory (decreases in the probability of independence) were associated with older age at injury, non-white race/ethnicity, not living alone at injury, not being productive prior to injury, lower levels of education, having Medicare or Medicaid as a payer source, lower FIM motor and cognitive discharge scores, higher DRS discharge scores, and increased rehabilitation length of stay. Changes in the shape of the SRS trajectory were associated with age, race/ethnicity, and FIM motor and cognitive scores.

Tables 4 and 5 summarize how two individuals, who differ in terms of only one characteristic and are equivalent on all other characteristics, are expected to differ in DRS and SRS outcomes at 1, 2, and 5 years post-injury. These tables also reflect how the differences in outcomes between these two individuals are expected to change over time by comparing the relative magnitude of the differences/odds ratios between 1, 2, and 5 years. For example, an individual who is 71 years old (25th percentile), compared to an individual who is 30 years old (75th percentile), is expected to have a DRS score that is 0.73 units higher at 1 year post-injury, 0.97 units higher at 2 years post-injury, and 1.67 units higher at 5 years post injury, given all other covariates are the same between the two individuals (see Table 4). Similarly, the odds of being independent are 1.06, 2.01, and 5.32 times greater at 1, 2, and 5 years post-injury, respectively, for a 30 year old as compared to a 71–year-old, given all other characteristics are the same (see Table 5). Careful inspection of Tables 4 and 5 will reveal that the disparities between individuals who differ only in terms of age increase over time, whereas differences between those who differ only in terms of race or sex tend to decrease with time.

Interactive Tool

The effects of the individual covariates on outcome trajectories may seem relatively small in magnitude; however the cumulative effect of differences between subjects in a multitude of different covariates is substantial. The complex relationship between the covariates and the trajectories of DRS and SRS over time can best be visualized through the use of an interactive tool (see Tool, Supplemental Digital Content 1). To illustrate the combined effects of person and injury factors, Figure 4 below shows trajectories of disability as measured by the DRS and probability of independence as measured by SRS for two case examples summarized in Table 6. The example cases were assigned several common features; most notably they are the same age (65 years old at the time of injury) and they sustained injuries of similar magnitude (based on CT scan, both were assigned evidence of intracranial compression, and intraventricular hemorrhage, but not punctate/petechial hemorrhages). The sample cases were made to differ on some demographic and rehabilitation indices (see Table 6). When we examine the associated trajectories of change over time (see Figure 4), we see that individuals who are similar to Case Example 1 are expected to have relatively low levels of disability as measured by DRS at 1 year post-injury, with a trajectory suggesting a very gradual increase in disability over years 3–5 post-injury (see Figure 4a). By contrast, individuals who are similar to Case Example 2 tend to have much higher DRS scores to start, and trajectories suggest recovery until around year 3 when there is a slow increase in disability. The example cases differ markedly on probability of independence over time as well; individuals represented by Case Example 1 have a high probability of independence as measured by SRS at Year 1, and independence declines that are very slow but steady over time, remaining relatively high even 5 years post-injury. Individuals who are similar to Case Example 2, on the other hand show a very low probability of independence at Year 1, and while independence likelihood does initially increase, after Year 3 the probability of independence returns again to near initial (1 year follow-up) levels (see Figure 4b).

DISCUSSION

Results of the current study are consistent with the notion that for many, moderate and severe TBI evolves into a chronic disease, as impairments to the brain and other organ systems may persist or progress over an individual's life span.[4,47,48] Here we saw an initial improvement in functioning and concurrent increase in the probability of independence between 1 and 2 years post injury, followed by a decline in functioning and decrease in probability of independence by 5 years post-injury. The current finding that the 5th year after TBI may represent an inflection point for functional decline is consistent with previous studies.[49–51]

However, results indicate considerable heterogeneity in outcomes across individuals, and examination of individual trajectories clearly indicates that many TBI survivors maintain the improvements seen during recovery for many years – and some continue to improve for many years after injury. Although these positive outcomes are not as widely recognized, this finding is not novel; prior studies have reported continued cognitive and/or functional improvement in a substantial minority of TBI survivors up to 30 years post-injury.[52–54] Here we found that some pre-injury factors as well as access to private insurance may be protective in that they seem to modulate the deleterious effects of TBI over time. Future efforts focused on identifying modifiable protective factors will be an important contribution to this work.

It is worth noting that although an individual's outcome at 2 and 5 years post-injury is heavily determined by functional status at Year 1, we found that multiple factors, including covariates that did not reach statistical significance, have a substantial cumulative impact on trajectories of function and independence over time. We found that although largely the same factors were associated both functional outcome (DRS) and probability of independence (SRS), each outcome was influenced by a different set of factors. The shape of the group mean trajectory for DRS was influenced by payor source, length of rehabilitation stay, and DRS score at discharge, while the group mean trajectory for SRS was influenced by age, race, FIM motor score and FIM cognitive score. The case examples help to illustrate that TBI outcomes are not simply a function of injury severity and age: holding age constant, we found that other demographic, lifestyle, and rehabilitation-related factors account for substantial differences in trajectories of change over time. The current finding is consistent with at least two prior studies which reported functional decline after TBI remained evident after adjusting for age,[52,55] suggesting that age alone should not exclude patients from receiving aggressive rehabilitation.

Some limitations should be considered in interpreting and applying the study findings. The study required the presence of data for at least three of the assessment intervals; multiple imputation strategies were utilized for those missing exactly one of the three assessments, however the analysis did exclude those missing two or three follow-up assessments. It should also be noted that the outcome measures included here (DRS and SRS) are subjective measures with follow-up scoring based on the self-assessment of people with injury or their proxy. Finally, it should be noted that the shape of the change trajectories presented here represent the best-fitting model for the data available. It is well known that many survivors of moderate-severe TBI continue to experience functional improvements with no clear evidence of functional decline even many years post-injury, and there are many factors that may influence positive long-term outcome trajectories that are not included in the NDB and therefore could not be modeled in the current study.

Conclusions

There are several unique contributions of the current study. To our knowledge this is the first study to model the impact of multiple factors on changes in outcome trajectories for the population of persons in the US who sustain a moderate or severe TBI. The current work, which provides a detailed description of how various factors influence longitudinal trajectories of clinical outcomes, is complementary to ongoing efforts aimed at developing informative and clinically accessible clinical prognostic tools for this patient population.[56] Here we examined the influence of these covariates on both disability status (DRS) and level of functional independence (SRS) in the same sample. We found that several demographic, lifestyle, and rehabilitation-related factors account for substantial differences in trajectories of change over time, suggesting that commonly investigated predictors of static outcomes (such as age and injury severity) are insufficient to explain patterns of change over time. We created an interactive tool that allows for examination of both the individual and simultaneous influence of many factors on functional outcomes after TBI. Considerable variance in outcome trajectories remains unexplained, and future studies that include more granular measurements of injury biomarkers, genetic data, and other factors known to influence functional ability will provide valuable extensions to this line of work.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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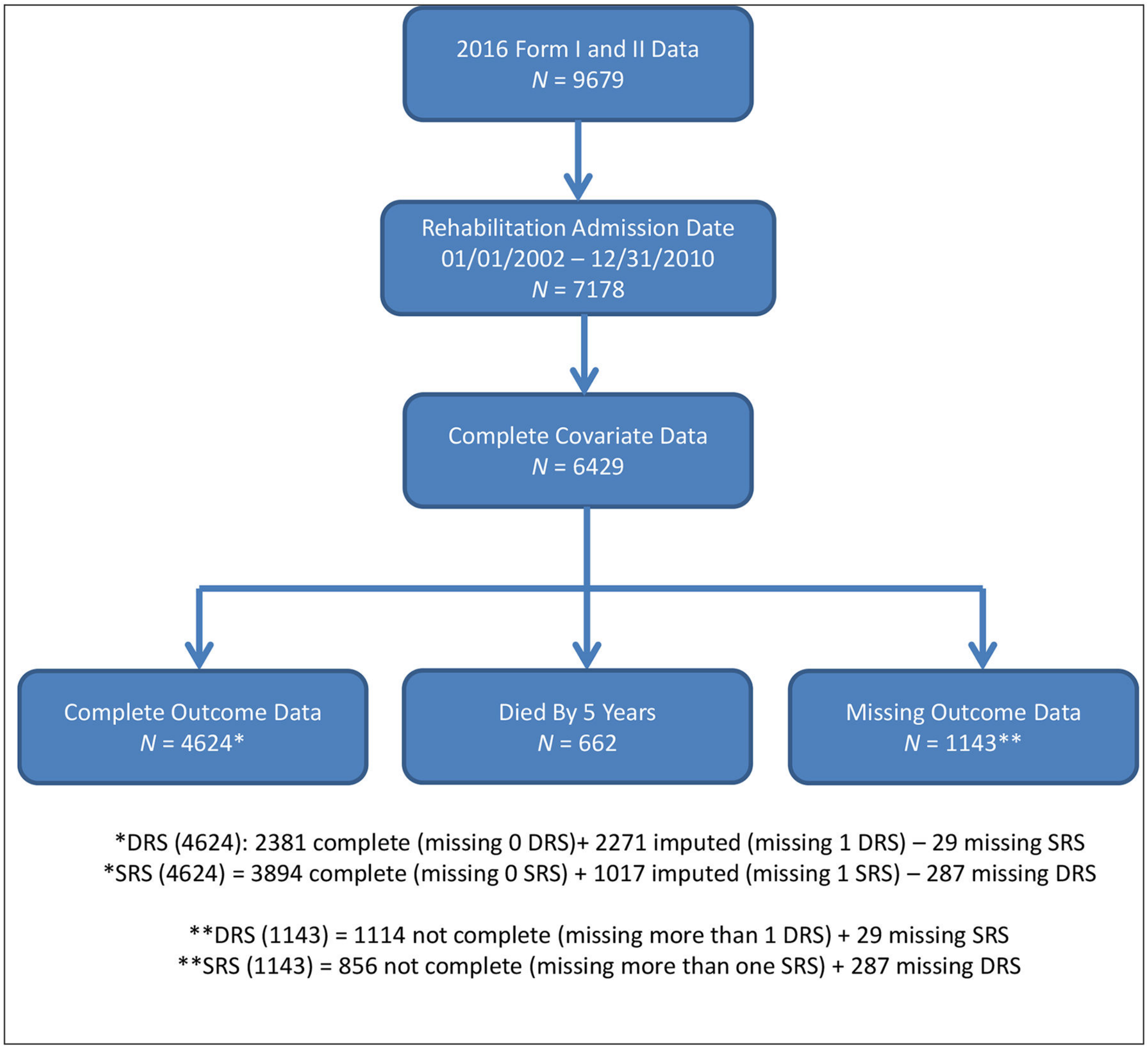

Figure 1:
Sample Flow Chart

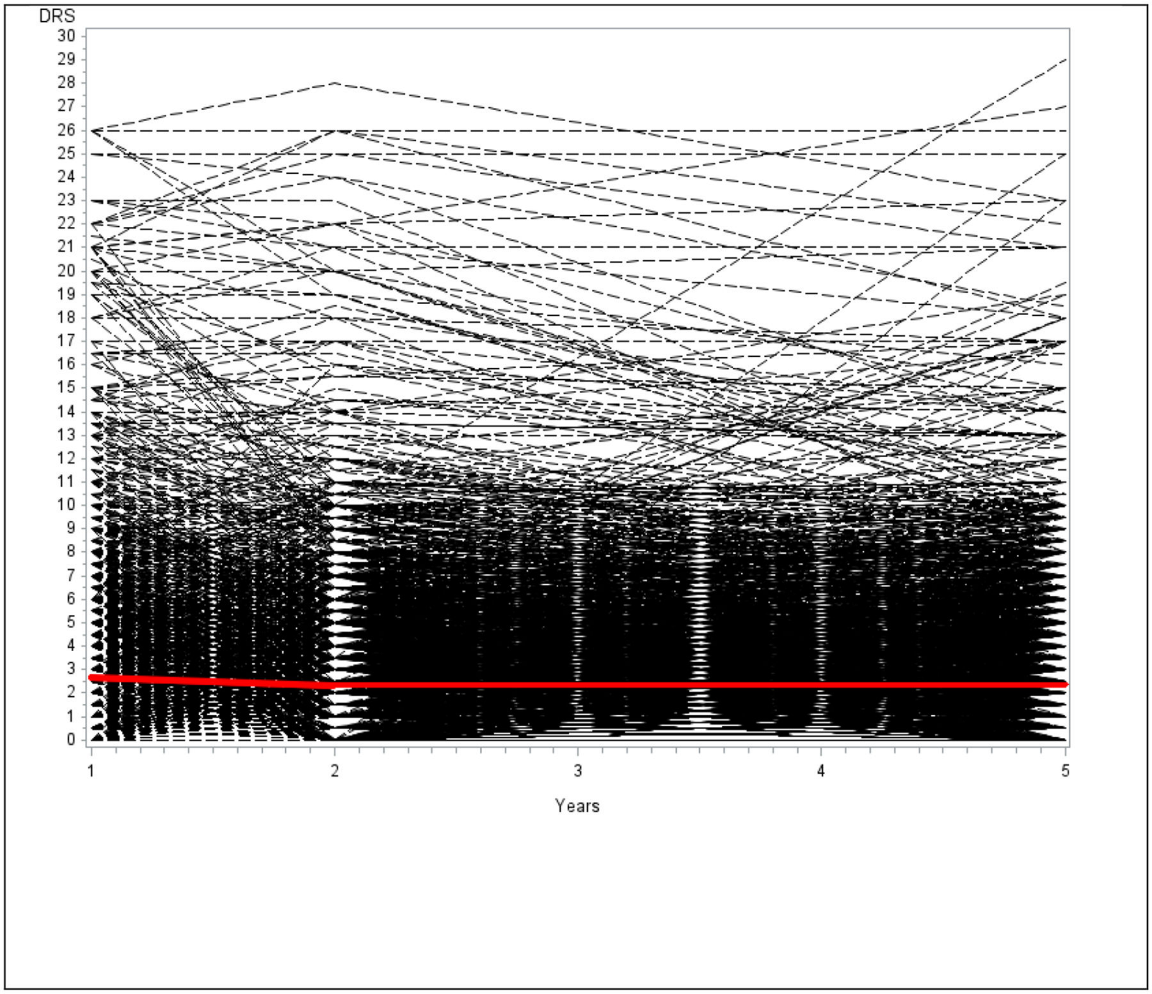

Figure 2:
Trajectory of DRS Scores over Time on Average (Red) and By Subject (Black)

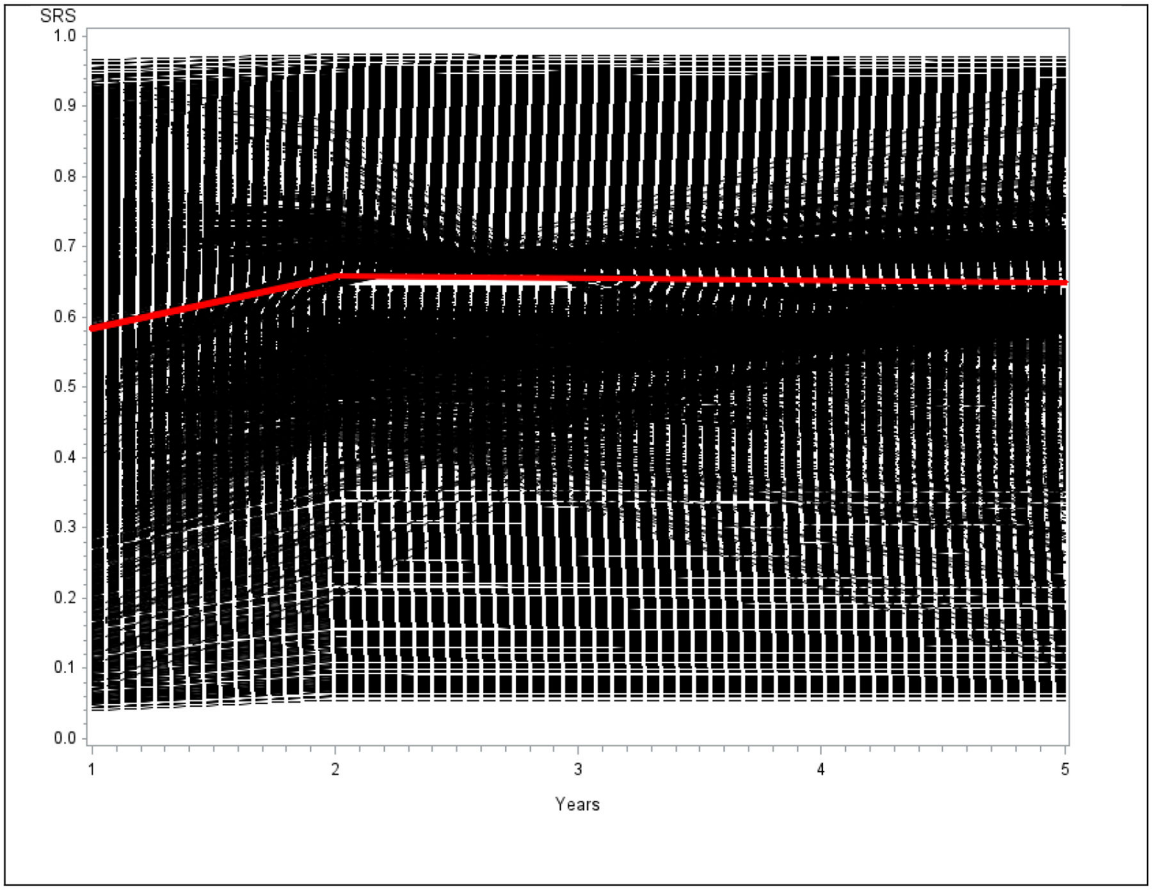

Figure 3:
Trajectory of the Probability of Independence over Time on Average (Red) and By Subject (Black)

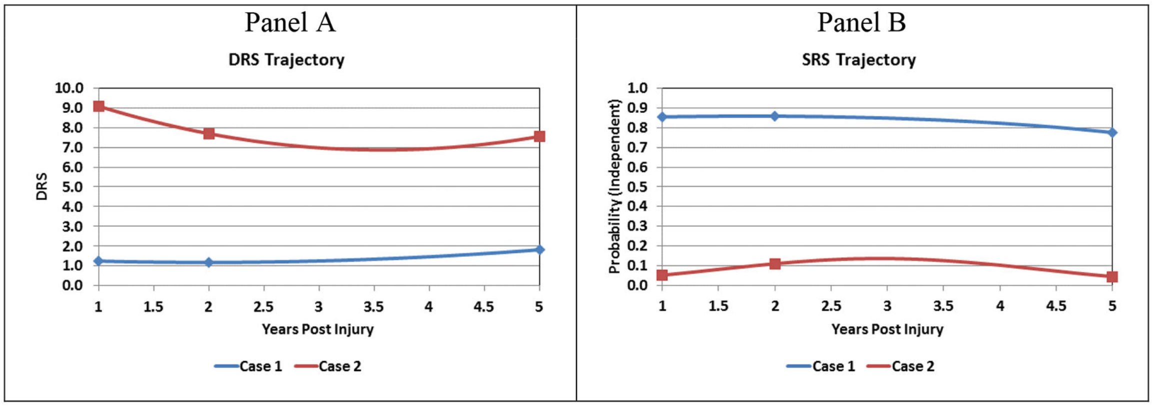

Figure 4:

Trajectory of Disability rating (Panel A) and Probability of Independence (Panel B) over Time for Case Example 1 (blue) and Case Example2 (red).

Table 1:

Continuous Sample Characteristics

	Unweighted		Weighted	
	Mean (SD)	**IQR**	**Mean (SD)**	**IQR**
Age at Injury	38.19 (17.52)	22 – 50	50.61 (20.66)	30 – 71
LOS Rehabilitation	26.50 (25.46)	12 – 31	18.38 (17.32)	8 – 21
FIM Motor Discharge	67.59 (17.78)	59 – 81	67.47 (15.24)	60 – 80
FIM Cognitive Discharge	24.02 (6.63)	20 – 29	24.56 (5.93)	21 – 29
DRS at Discharge	6.24 (3.73)	4 – 7	5.86 (3.27)	4 – 7

SD = Standard Deviation; IQR = Interquartile Range

Table 2:

Categorical Sample Characteristics

	Unweighted Percent	Weighted Percent
Sex		
Male	73.03%	64.53%
Female	26.97%	35.47%
Race		
White	71.09%	77.36%
Not White	28.91%	22.64%
Pre-Injury Marital Status		
Married	32.85%	40.01%
Not Married	67.15%	59.99%
Pre-Injury Living Situation		
Alone (incl. Roommate)	23.55%	28.01%
Not Alone	76.45%	71.99%
Pre-Injury Employment Status		
Productive (Employed/Student/Retired)	85.92%	86.36%
Not Productive (Other)	14.08%	13.64%
Pre-Injury Education Level		
High School or Less	60.71%	59.38%
More than High School	39.29%	40.62%
Pre-Injury Substance Abuse		
Yes	43.47%	33.73%
No	56.53%	66.27%
Primary Payment Source		
Medicaid/Medicare	32.57%	45.07%
Other	67.43%	54.93%
Intracranial Compression		
Yes	44.33%	44.09%
No	55.67%	55.91%
Punctate/Petechial Hemorrhages		
Yes	29.43%	20.62%
No	70.57%	79.38%
Intraventricular Hemorrhage		
Yes	27.77%	24.98%
No	72.23%	75.02%

Table 3:

Summary of DRS and SRS Outcomes over Time

	Year 1	Year 2	Year 5
DRS, Mean (SD)	2.53 (2.91)	2.37 (2.78)	2.71 (2.98)
SRS, % Independent	57.69	62.41	60.04

SD = Standard Deviation *Interquartile range for DRS at all 3 time points is 0–4.

Table 4:

Individual Comparisons[a] of Mean DRS Scores among Covariate Levels at 1, 2, and 5 Years Post-Injury

		Year 1			Year 2			Year 5		
Varying Characteristic	**Comparison**	**Difference**	**95% CI**	***p*-value**	**Difference**	**95% CI**	***p*-value**	**Difference**	**95% CI**	***p*-value**
Age	71 years vs. 30 years	0.73	(0.54, 0.92)	< 0.0001	0.97	(0.78, 1.15)	< 0.0001	1.67	(1.48, 1.85)	< 0.0001
Sex	Male vs. Female	0.05	(−0.11, 0.20)	0.5501	0.02	(−0.13, 0.17)	0.7951	0.02	(−0.12, 0.17)	0.7473
Race	Not White vs. White	0.53	(0.38, 0.68)	< 0.0001	0.42	(0.27, 0.57)	< 0.0001	0.11	(−0.04, 0.25)	0.1426
Marital Status	Not Married vs. Married	0.14	(−0.04, 0.33)	0.1243	0.12	(−0.06, 0.30)	0.1791	0.25	(0.08, 0.42)	0.0047
Living Situation	Not Alone vs. Alone	0.03	(−0.15, 0.21)	0.7566	0.03	(−0.15, 0.20)	0.7505	0.06	(−0.11, 0.23)	0.4650
Employment	Not Productive vs. Productive	0.37	(0.17, 0.57)	0.0004	0.39	(0.19, 0.59)	0.0001	0.43	(0.24, 0.62)	< 0.0001
Education	HS or Less vs. More than HS	0.45	(0.30, 0.59)	< 0.0001	0.52	(0.38, 0.66)	< 0.0001	0.59	(0.45, 0.73)	< 0.0001
Problem Use	Yes vs. No	0.14	(0.00, 0.29)	0.0505	0.11	(−0.03, 0.25)	0.1276	0.04	(−0.10, 0.18)	0.5643
Payer Source	Medicare/Medicaid vs. Other	0.54	(0.39, 0.70)	< 0.0001	0.66	(0.51, 0.81)	< 0.0001	0.55	(0.40, 0.70)	< 0.0001
Rehabilitation LOS	21 days vs. 8 days	0.29	(0.26, 0.33)	< 0.0001	0.22	(0.19, 0.26)	< 0.0001	0.19	(0.15, 0.22)	< 0.0001
FIM Motor Discharge	60 vs. 80	0.74	(0.63, 0.85)	< 0.0001	0.67	(0.57, 0.78)	< 0.0001	0.66	(0.56, 0.77)	< 0.0001
FIM Cognitive Discharge	21 vs. 29	0.39	(0.26, 0.49)	< 0.0001	0.41	(0.30, 0.52)	< 0.0001	0.39	(0.28, 0.49)	< 0.0001
DRS Discharge	7 vs. 4	0.91	(0.83, 1.00)	< 0.0001	0.70	(0.62, 0.79)	< 0.0001	0.61	(0.53, 0.70)	< 0.0001
CT Compression	Yes vs. No	0.13	(−0.01, 0.27)	0.0730	0.08	(−0.06, 0.21)	0.2728	0.11	(−0.02, 0.24)	0.0959
CT Punctate/Petechial	Yes vs. No	−0.11	(−0.26, 0.04)	0.1577	−0.09	(−0.24, 0.06)	0.2457	−0.09	(−0.24, 0.05)	0.2077
CT Intraventricular	Yes vs. No	0.05	(−0.11, 0.20)	0.5601	0.08	(−0.07, 0.23)	0.3080	0.19	(0.04, 0.34)	0.0121

[a]Comparison between two individuals who differ in terms of one characteristics only and are the same for all other covariates

CI = Confidence Interval

Table 5:

Individual Comparison[a] of SRS (Odds of Independence) among Covariate Levels at 1, 2, and 5 Years Post-Injury

		Year 1			Year 2			Year 5		
Varying Characteristic	**Comparison**	**OR**	**95% CI**	***p*-value**	**OR**	**95% CI**	***p*-value**	**OR**	**95% CI**	***p*-value**
Age	30 years vs. 71 years	1.06	(0.79, 1.42)	0.6971	2.01	(1.52, 2.66)	< 0.0001	5.32	(3.92, 7.22)	< 0.0001
Sex	Male vs. Female	1.35	(1.06, 1.72)	0.0143	1.12	(0.89, 1.42)	0.3229	1.15	(0.89, 1.47)	0.2867
Race	White vs. Not White	2.26	(1.75, 2.90)	< 0.0001	1.37	(1.07, 1.75)	0.0123	1.54	(1.19, 2.01)	0.0012
Marital Status	Married vs. Not Married	0.99	(0.74, 1.32)	0.9341	1.19	(0.90, 1.58)	0.2308	1.46	(1.08, 1.98)	0.0137
Living Situation	Alone vs. Not Alone	1.75	(1.31, 2.35)	0.0002	1.76	(1.32, 2.35)	0.0001	1.82	(1.33, 2.47)	0.0002
Employment	Productive vs. Not Productive	1.01	(0.74, 1.37)	0.9581	1.40	(1.05, 1.88)	0.0241	1.36	(1.00, 1.85)	0.0537
Education	HS or Less vs. More than HS	2.32	(1.84, 2.92)	< 0.0001	1.76	(1.40, 2.21)	< 0.0001	1.92	(1.50, 2.44)	< 0.0001
Problem Use	No vs. Yes	1.22	(0.97, 1.55)	0.0944	0.95	(0.75, 1.20)	0.6642	1.10	(0.86, 1.41)	0.4450
Payer Source	Medicare/Medicaid vs. Other	1.75	(0.36, 2.26)	< 0.0001	2.12	(1.66, 2.70)	< 0.0001	1.79	(1.38, 2.31)	< 0.0001
Rehabilitation LOS	8 days vs. 21 days	1.43	(1.30, 1.57)	< 0.0001	1.46	(1.33, 1.59)	< 0.0001	1.18	(1.09, 1.28)	< 0.0001
FIM Motor Discharge	80 vs. 60	2.06	(1.71, 2.46)	< 0.0001	1.49	(1.25, 1.77)	< 0.0001	1.38	(1.15, 1.65)	0.0005
FIM Cognitive Discharge	21 vs. 29	1.17	(0.98, 1.40)	0.0755	1.52	(1.28, 1.80)	< 0.0001	1.58	(1.31, 1.89)	< 0.0001
DRS Discharge	4 vs. 7	1.36	(1.17, 1.57)	< 0.0001	1.30	(1.13, 1.49)	0.0002	1.52	(1.31, 1.76)	< 0.0001
CT Compression	No vs. Yes	1.13	(0.91, 1.42)	0.2642	1.06	(0.85, 1.31)	0.6026	1.00	(0.79, 1.26)	0.9914
CT Punctate/Petechial	No vs. Yes	0.99	(0.76, 1.29)	0.9519	0.95	(0.73, 1.23)	0.6959	0.99	(0.75, 1.30)	0.9155
CT Intraventricular	No vs. Yes	0.99	(0.77, 1.28)	0.9477	1.15	(0.90, 1.48)	0.2605	1.34	(1.03, 1.75)	0.0291

[a]Comparison between two individuals who differ in terms of one characteristics only and are the same for all other covariates

Odds = Probability (Independent) / Probability (Not Independent)

Odds Ratio (OR) = Odds for individual 1 / Odds for individual 2

CI = Confidence Interval

Table 6:

Covariate values for Case Examples Shown in Figure 4

Covariates	Case 1	Case 2
Sex	Male	Male
Race	**White**	**Not White**
Pre-Injury Marital Status	Married	Married
Pre-Injury Living Situation	Not Alone	Not Alone
Pre-Injury Employment Status	Productive	Productive
Pre-Injury Level of Education	More than HS	More than HS
Primary Payer Source	Not Medicare or Medicaid	Not Medicare or Medicaid
Pre-Injury Substance Abuse	**Yes**	**No**
CT Compression	Yes	Yes
CT Punctate	No	No
CT Intraventricular Hemorrhage	Yes	Yes
Age at Injury (16 – 94)	65	65
LOS Rehabilitation (≥ 0)	**15**	**30**
FIM Motor Discharge (13 – 91)	**80**	**30**
FIM Cognitive Discharge (5 – 35)	**30**	**15**
DRS Discharge (0 – 29)	**5**	**20**