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Distal and Proximal Predictors of Rehospitalization Over 10 Years Among Survivors of TBI: A National Institute on Disability, Independent Living, and Rehabilitation Research Traumatic Brain Injury Model Systems Study

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Abstract

Objective: To describe the rates and causes of rehospitalization over a 10-year period following a moderate-severe traumatic brain injury (TBI) utilizing the Healthcare Cost and Utilization Project (HCUP) diagnostic coding scheme.

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Setting: TBI Model Systems centers.

Participants: Individuals 16 years and older with a primary diagnosis of TBI.

Design: Prospective Cohort Study.

Main Measures: Rehospitalization (and reason for rehospitalization) as reported by participants or their proxies during follow-up telephone interviews at 1-, 2-, 5-, and 10-years post-injury.

Results: The greatest number of rehospitalizations occurred in the first-year post-injury (23.4% of the sample), and the rates of rehospitalization remained stable (21.1%–20.9%) at years 2 and 5 and then decreased slightly (18.6%) at year 10 post-injury. Reasons for rehospitalization varied over time, but seizure was the most common reason at years 1, 2, and 5 post-injury. Other common reasons were related to need for procedures (e.g., craniotomy or craniectomy) or medical comorbid conditions (e.g., diseases of the heart, bacterial infections, or fractures). Multivariable logistic regression models showed that FIM motor score at time of discharge from inpatient rehabilitation was consistently associated with rehospitalization at all time points. Other factors associated with future rehospitalization over time included a prior history of rehospitalization, presence of seizures, need for craniotomy/craniectomy during acute hospitalization, as well as older age and greater physical and mental health comorbidities.

Conclusion: Using diagnostic codes to characterize reasons for rehospitalization may facilitate identification of baseline (e.g., FIM Motor score or craniotomy/craniectomy) and proximal (e.g., seizures or prior rehospitalization) factors that are associated with rehospitalization. Information about reasons for rehospitalization can aid health care system planning. By identifying those recovering from TBI at higher risk for rehospitalization, providing closer monitoring may help to decrease the healthcare burden by preventing rehospitalization.

Keywords

traumatic brain injury; chronic health; longitudinal outcomes; rehospitalization

Introduction

Traumatic brain injury (TBI) is increasingly conceptualized as a chronic health condition with lifelong and, in some cases, progressive health problems that warrant ongoing monitoring by clinicians with expertise in the field of brain injury medicine[1,2]. Individuals with a moderate-severe TBI appear to be at risk for medical and mental health comorbidities for many years after injury[3–6], and this disease burden has been found to have an adverse relationship with functional outcome[7]. Factors such as age, premorbid and post-injury health conditions may interact to enhance this risk[8].

Readmission to the hospital following an inpatient rehabilitation unit stay due to new TBI may be regarded as a reflection of post-injury health and related healthcare burden[9]. Recent work has demonstrated an important demographic shift toward aging of the TBI rehabilitation population[10]. One study showed an association of poorer outcomes among older adults hospitalized within 1-year following TBI[11], and another found rehospitalization to associated with poorer participation in one’s own health management[12]. Rehospitalization may have many detrimental consequences as it may disrupt community re-integration,

cause the loss of a patient's home care services, and lead to secondary medical complications (such as, nosocomial infections) that can result in significant morbidity and possibly mortality. Rehospitalization has been increasingly tied to hospital reimbursement, representing an obstacle to value-based care and therefore is a growing financial concern for inpatient rehabilitation units and hospital systems as a whole.

Several studies have examined risk factors for rehospitalization. One study found that in a 3-year follow-up period after TBI, the risk of rehospitalization increased with male gender, older age, greater injury severity, mechanism of injury and co-morbid physical or mental health problems[13]. A prospective study found rehospitalization rates increase with severity of TBI and were highest for those with disorders of consciousness[14]. Another study of 510 participants that looked at a 9-month follow-up period found that various medical and surgical reasons were found to contribute to an increased risk of rehospitalization in 28% of the participants[9]. A study that looked at outcomes following neurosurgical management of TBI found that those who required hemicraniectomy as opposed to craniotomy had a higher rate of rehospitalization[15]. Older adults with multiple co-morbidities were found to have an increased rate of rehospitalization at 1-year post-injury[8]. Together, these studies demonstrate that more severe TBI, co-morbid conditions, and more invasive surgical procedures generally pose higher risk of rehospitalization.

It is clear that rehospitalization is common and poses major health care burden for patients recovering from TBI. However, prior studies are limited by brief follow-up timeframes[8,9,11,16], and used only broad imprecise categories to characterize primary reasons for rehospitalization[16,17]. A prior TBI Model Systems (TBIMS) study examined longer-term rates of rehospitalization up to 10 years following moderate-severe TBI and inpatient rehabilitation and found rates were highest in the first year following injury (28%) and mostly attributable to orthopedic causes. At successive time points (2-, 5-, and 10-years post-injury), rates of rehospitalization are relatively consistent (22.1%–23.4%); with general health reasons being the most common[17]. More detailed information about risk profiles and reasons for rehospitalization have since been added to the TBIMS National Database (NDB). The goal of this paper is to use this expanded diagnostic coding scheme in the TBIMS NDB to investigate the most common reasons for rehospitalization over 10 years following TBI. We further expand upon prior work that included only baseline predictors[9,13,14,16,17] by using information collected following hospital discharge to identify risk factors that are more proximal to rehospitalization.

Methods

Data Source and Participants

Data from the current study were collected as part of the TBIMS NDB[18]. The TBIMS is a multicenter prospective longitudinal study of individuals with moderate to severe TBI enrolled during inpatient rehabilitation and who are followed prospectively post-injury at 1, 2, 5, and every 5 years thereafter. The data used in the current study come from sites funded by the National Institute on Disability, Independent Living and Rehabilitation Research (NIDILRR) within the Agency on Community Living in Health and Human Services. TBIMS inclusion criteria include having sustained a TBI meeting at least 1

of following criteria: Glasgow Coma Scale score less than 13 on emergency admission (not because of intubation, sedation, or intoxication), loss of consciousness ≥ 30 minutes unrelated to sedation or intoxication, post-traumatic amnesia > 24 hours, or trauma-related intracranial abnormality on neuroimaging. In addition, all participants must be 16 years or older, receive their medical care within the TBIMS affiliated system within 72 hours of injury, and complete inpatient rehabilitation within the system. Participants provide consent or consent can occur via legal proxy. More details on the database, data collected during inpatient rehabilitation (Form I) and at the follow up assessments (Form II) are available at www.tbindsc.org. Participants in the current study had TBIMS follow-up interviews on or after October 1st, 2017. At this date, the rehospitalization variable was updated in the TBIMS NDB (detailed below). Participants were included in the current investigation if they had at least one follow up at 1-, 2-, 5-, or 10-years post-injury and provided information on rehospitalization via self- or proxy report.

Variables

Primary outcome: Rehospitalization—Information is collected from participants with TBI and/or their proxies regarding whether they were ever rehospitalized after discharge from inpatient rehabilitation, and if so, how many rehospitalizations (up to five), as well as the primary reason for each rehospitalization. The query refers to all types of causes for any inpatient admission greater than 24 hours in any hospital, but does not include emergency department or urgent care visits <24 hours. Per the TBIMS follow-up protocol, participants were asked at 1-, 2-, 5- and 10-years post-injury whether they had been rehospitalized in the past year.

To characterize reasons for rehospitalization, we used the rehospitalization coding system from the Healthcare Cost and Utilization Project (HCUP) National Readmissions Database (NRD) which was expanded in 2015 with the introduction of ICD-10 diagnostic codes. The NRD can be used to track vital information related to hospital readmissions including cost-analysis as it relates to hospital reimbursements. Data collectors across TBIMS centers were trained in coding reasons for each reported rehospitalization into 1 of 18 Level 1 HCUP diagnostic codes (expanded from 8 categories in the prior coding system), these included: infectious diseases, neoplasms, endocrine/nutritional and metabolic diseases, diseases of the blood and blood-forming organs, mental illness, diseases of the nervous system and sense organs, diseases of the circulatory system, diseases of the respiratory system, diseases of the digestive system, diseases of the genitourinary system (not including urinary tract infections), complications of pregnancy, diseases of the skin and subcutaneous tissue, diseases of the musculoskeletal system and the connective tissue, congenital anomalies, certain conditions originating in the perinatal period, injury and poisoning (including craniotomy or craniectomy), symptoms/signs of an ill-defined condition and factors influencing health status and unclassified residual codes. Among each of the 18 Level 1 diagnostic codes, data collectors further classified participants' reasons for rehospitalization into a Level 2 HCUP diagnosis code.

Demographic variables and covariates—All information was collected per standard TBIMS protocols. Unlike a prior rehospitalization study[17] that only used baseline predictors,

we wanted to leverage the full breadth available longitudinal predictors for odds of rehospitalization up to 10 years post-injury. To this end, we characterized the sample at three time points: 1) baseline (i.e., acute hospitalization and inpatient rehabilitation), 2) in the wave prior to assessment of rehospitalization (except at year 1) and 3) at the same wave of assessment of rehospitalization. The variables collected at these three time points were the predictors for rehospitalization at year 1-, 2-, 5-, and 10-years post-injury. The included baseline variables were consistent with a TBIMS prior study of rehospitalization[17], and additional variables were selected from clinical experience regarding associations between covariates and TBI outcomes.

The baseline variables included: sex, race (white and non-white), education (less than high school, greater than or equal to high school), inpatient rehabilitation payor source (governmental insurance, other), length of stay during inpatient rehabilitation, Functional Independence Measure (FIM) Motor subscale score at rehabilitation discharge, FIM Cognitive subscale score at rehabilitation discharge, cranial surgery status (craniotomy or craniectomy), pre-index history of TBI (self-reported history of TBI prior to index TBI as determined by the Ohio State University TBI Identification Method).

The variables measured at prior TBIMS follow-up waves included: problem substance use (defined if participant in the past month has taken illicit drugs, binge drunk, drink greater than 14 drinks per week (males) or 7 drinks per week (females)), post-index rehospitalization (rehospitalization in the prior wave), Participation Assessment with Recombined Tools - Objective (PART-O) summary (sum of three PART-O subscale scores (Out-and-About, Productivity, Social) divided by three), driving independence (participant reports driving vehicle independently).

The variables measured at the same follow-up interview as the rehospitalization variable included: age group (16–29, 30–49, 50–64, 65+), seizures in the past year, total number of self-reported medical comorbidities (0–1, 2+), and total number of self-reported mental health comorbidities (0–1, 2+). The list of medical conditions considered were: hypertension, congestive heart failure, myocardial infarction, other heart conditions, stroke, emphysema, high blood cholesterol, diabetes, pneumonia, liver, rheumatoid arthritis, osteoarthritis, sleep disorder, cataracts, chronic pain, dementia, movement disorder. The list of mental health conditions considered were: alcoholism, drug addiction, depression, anxiety, panic attacks, bipolar disorder, attention deficit disorder/attention deficit hyperactive disorder, obsessive compulsive disorder, and post-traumatic stress disorder.

Data analysis

We compared demographic and clinical characteristics by rehospitalization (yes/no) at 1, 2, 5, and 10- years post-injury using chi-square tests for categorical characteristics, two sample *t*-tests for normally distributed continuous characteristics, and Wilcoxon rank-sum tests for markedly skewed continuous characteristics. We calculated rates (per 1000 persons) for each reason for rehospitalization, and the top 10 reasons for rehospitalization at each follow-up time point. We ran a Multivariable Logistic Regression Model evaluating predictors associated with the likelihood of rehospitalization at 1-, 2-, 5-, and 10-years post-injury. As a sensitivity analysis, we ran an Ordinal Logistic Regression Model evaluating predictors

of the likelihood of 0, 1, or 2+ rehospitalizations. All analyses were performed in SAS 9.4 (Cary, NC).

Results

Description of the sample

We investigated four cross-sectional samples at 1 year (n=1,203), 2 years (n=1,129), 5 years (n=1,017), and 10 years (n=894) post-injury. We documented the descriptive characteristics associated with rehospitalization at each follow-up year in Table 1. Overall, characteristics consistently associated with rehospitalization at each time point included older age group, lower FIM Motor at inpatient rehabilitation discharge, seizures in the past year, and greater number of medical and mental health comorbidities.

Rates of Rehospitalization

The proportion of the sample rehospitalized at 1 year, 2 years, 5 years, and 10 years post-injury were 23.4%, 21.1%, 20.9%, and 18.6%, respectively.

Reasons for Rehospitalization

The top 10 reasons for rehospitalization, and associated rates, at 1-, 2-, 5-, and 10-years post-injury are displayed in Table 2. The top reason for rehospitalization at 1-, 2-, and 5-years post-injury was “Epilepsy; convulsions;” while at year 10 the most common reason was “fractures; treatment of fractures or dislocation” (closely followed by Epilepsy). “Intracranial injury; craniotomy or craniectomy procedure” was common at Years 1 and 2, and then again at Year 10. “Bacterial infection” was common through Year 5, and “Mood Disorders” and “Anxiety Disorders” made the top ten in Years 5 and 10, respectively. Other top reasons for rehospitalization in the first 10 years post-injury were: “Diseases of the heart; heart procedures”, “Fractures; treatment of fractures or dislocation”, “Diseases of the urinary system; operations on the urinary system,” and “Cerebrovascular disease/stroke.” We present the detailed rates of rehospitalization by body system (Level 1 HCUP classifications) in Supplemental Table 1, and particular diagnoses (Level 2 HCUP classifications) in Supplemental Table 2.

Predictors of Likelihood of Rehospitalization at year 1, 2, 5, and 10 post-injury

The results of the multivariable logistic regression models for each follow-up year are displayed in Table 3. At 1 year, the baseline variables significantly associated with rehospitalization were FIM motor at rehabilitation discharge (OR=0.98, 95% CI: 0.97, 0.99) and craniotomy or craniectomy (OR=2.29, 95% CI: 1.64, 3.22). The year 1 variables measured at the same cross-sectional time point significantly associated with rehospitalization were: seizures in the last year (OR=5.10, 95% CI: 3.40, 7.64) and number of medical comorbidities (OR=2.89, 95% CI: 2.01, 4.15).

At year 2, the baseline variables significantly associated with rehospitalization were: non-governmental insurance (OR=0.56, 95% CI: 0.54, 0.83), FIM motor at rehabilitation discharge (OR=0.99, 95% CI: 0.97, 0.99), and pre-index history of TBI (OR=0.53, 95% CI: 0.33, 0.83). The prior wave (year 1) variables associated with rehospitalization were:

rehospitalization at year 1 (OR=3.24, 95% CI: 2.20, 4.78). The year 2 concurrently measured variables that were significantly associated with rehospitalization were: age strata 30–49 (OR=2.12, 95% CI: 1.21, 3.73) and 50–64 (OR=1.91, 95% CI: 1.04, 3.51) relative to age 16–29, seizures in the past year (OR=3.00, 95% CI: 1.77, 5.06), total number of medical comorbidities (OR=1.69, 95% CI: 1.01, 2.61), and number of mental health comorbidities (OR=1.67, 95% CI: 1.13, 2.47).

At year 5, the only baseline variables associated with rehospitalization was FIM Motor at rehabilitation discharge (OR=0.98, 95% CI: 0.97, 0.99). Prior wave rehospitalization at year 2 was significantly associated with year 5 rehospitalization (OR=2.24, 95% CI: 1.49, 3.38). The variables collected at the year 5 time point that were significantly associated with rehospitalization were: seizures in the past year (OR=3.74, 95% CI: 2.22, 6.31), greater number of medical (OR=1.61, 95% CI: 1.06, 2.43) and mental health comorbidities (OR=1.57, 95% CI: 1.06, 2.30).

At year 10, no baseline variables were associated with rehospitalization. Prior wave (year 5) rehospitalization was associated with higher odds of year 10 rehospitalization (OR=3.25, 95% CI: 2.07, 5.10). The year 10 variables associated with rehospitalization were: age 65+ (OR=4.34, 95% CI: 1.58, 11.93), seizures in the past year (OR=3.64, 95% CI: 1.98, 6.69), and greater number of medical comorbidities (OR=2.10, 95% CI: 1.31, 3.39).

The model AUCs for the 1-, 2-, 5-, and 10-year models were all >0.7 (range 0.739–0.782), indicating a moderately strong discrimination of rehospitalization based on the variables included.

The results of our sensitivity analysis that evaluated predictors of 0, 1, and 2+ rehospitalizations for each follow-up year were mostly similar to the primary binary logistic regression models (see Supplemental Table 3).

Discussion:

Rehospitalization following discharge from acute inpatient rehabilitation is an indicator of long-term health and well-being that also reflect some of the health-care system and economic impact of TBI. Here, we expand upon prior TBIMS investigations of rehospitalization[16,17] by using newly collected and highly detailed rehospitalization data from the TBIMS NDB to characterize the most common reasons for rehospitalization up to 10 years post-injury, and investigated baseline, prior visit, and concurrent predictors of past-year rehospitalization at each follow-up interval.

Rates of rehospitalization decreased slightly over time, from 23.4% to 18.6% by Year 10. There was some variability in the most common reasons for rehospitalization across the follow-up periods. However, seizure disorder was the single most common cause for rehospitalization at years 1, 2, and 5 and the second most common at year 10. Though it is possible that a seizure disorder may have pre-dated (or even caused) the index TBI[19], these hospitalizations likely reflect complications of posttraumatic epilepsy (PTE), defined as recurrent late-onset seizures after TBI which affects up to 25% of individuals with moderate-severe TBI[20–22].

Some of the rehospitalizations in the first year after injury likely reflect planned procedures relating to the injury itself, such as invasive neurosurgical procedures (craniotomy and craniectomy) for deferred or elective cranioplasty, complications such as hydrocephalus or infection, or shunt revisions. Similarly, treatment of fractures may reflect surgical revision or correction of injuries sustained concurrently with the head trauma.

However, the fact that these same rehospitalization reasons are so common 5- and 10 years post-injury (at which point “Fractures/Treatment of fractures/dislocation is the number one reason for rehospitalization), is also noteworthy. Together with the prevalence of other injuries related to “external causes” at years 2 and 5, and “trauma-related” joint disorders and dislocations at years 5 and 10, these findings may reflect risk for re-injury among those with TBI which has been extensively documented[23,24]. Given the low likelihood of craniotomy or craniectomy relating to the index injury is taking place 10 years later, the hospitalizations for “intracranial injury” at year 10 may represent new TBIs. Further, and consistent with our prior work, rates of psychiatric hospitalization increased over time[17].

Cerebrovascular disease/stroke was among the top causes for rehospitalization at years 1, 2, and 5; this is consistent with prior evidence of increased risk for acute ischemic stroke following TBI[25] and also the longer-term risk for ischemic and hemorrhagic stroke[26,27]. The causes for this association are unknown, but may in part be related to known or occult traumatic cervical vascular injury concurrent with their TBI. Other common causes of rehospitalization may be less closely associated with the initial injury. Bacterial infections and cardiac conditions are common reasons for hospitalization in the general population[28]; that said, there is now more known on cardiac manifestations in patients with TBI, including theories on the neurocardiac axis[29]. Also, those with TBI are more likely to develop chronic diseases such as heart disease[30]. Diseases or operations involving the urinary system were also common; although TBI generally does not cause true neurogenic bladder as with spinal cord lesions, many patients have difficulty with higher level urinary control leading to incontinence and/or retention[31] along with co-occurring spinal cord injury. Admissions may be from complicated urinary tract infections or complications from remote histories of urinary tract infections or prolonged use of catheterization.

Our investigation into predictors of rehospitalization indicated that the most stable baseline predictor of past-year rehospitalization across follow-up visits at years 1, 2, and 5 was lower FIM motor score at rehabilitation discharge, which replicates prior work in the TBIMS National Database that exclusively investigated baseline predictiors.[17] Notably, the finding that no baseline predictors were associated with rehospitalization risk by 10 years underscores the importance of including prior-visit and concurrent time-varying covariates in models predicting remote TBI outcomes. When incorporating information collected at the prior and concurrent study visits, we found that prior rehospitalization, past-year seizure, and greater burden of medical and/or psychiatric comorbidities were consistent predictors of rehospitalization. There was some evidence that middle-aged participants were more likely to be rehospitalized than their younger counterparts (i.e., at Year 2) in that older age (i.e., age 65+) was significantly associated with increased risk for rehospitalization at the 10-year follow-up. This finding is consistent with recent TBIMS National Database research[32] that

found that the negative effects of injury chronicity are most pronounced among older adults with TBI.

There are limitations to this project that warrant mention. The TBIMS NDB includes individuals who receive care at inpatient rehabilitation facilities with specialized TBI units and therefore findings may not generalize to all patients recovering from TBI. However, this limitation is mitigated by previous research demonstrating that the TBIMS NDB is representative of all patients receiving inpatient rehabilitation for TBI in the United States[33]. The present study used a recently introduced rehospitalization variable from 2017 and with our current sample, we were limited in our ability to examine subgroups who may be differentially impacted by TBI and access to care including payor source[34] e.g., workers compensation) and race/ethnicity[35] (e.g., hispanic). Future studies with larger samples should use more granular categorizations of predictors of rehospitalization to facilitate more meaningful interpretations. Information on rehospitalization was collected via self-report or proxy-report and therefore may be subject to underreporting or even over-reporting. Additionally, there may be selection bias based on those having more medical problems and hospitalizations being more prone to complete their follow-up visits[36]. We also do not have data in the TBIMS on whether rehospitalization were planned or unplanned. In addition, coding reasons for rehospitalization was done by study staff based on structured protocols but there could be some miscategorization despite rigorous training and oversight. Future research would benefit from studying population cohorts that include individuals with and without TBI to better understand the specific medical diagnoses more prevalent among people with TBI. Also, we advise more research that uses objective health care claims data containing supplemental information from that available in self-report interviews, such as costs, duration of subsequent hospital stays, and surgical and medical interventions received. Important strengths of the current study, which extends findings from previously published papers on rehospitalization following moderate-severe TBI[17,37,38], include long length of follow-up, detailed categorization of reasons for rehospitalization, and inclusion of proximal (prior visit) and concurrent (same visit) predictors in all models rather than relying exclusively on baseline predictors of long-term rehospitalization risk.

Taken together, these findings reinforce the need for ongoing care and surveillance, at least among a subset of long-term survivors of moderate-severe TBI; these needs are not limited to older adults. Rehospitalizations may result from medical or mental health deterioration, under-treatment, ineffective treatment and/or non-adherence to prescribed medications and care regimens. Current findings reiterate the need for regular and ongoing surveillance and long-term care, including general and specialized care to manage seizures and other late complications of TBI. Thoughtfully deployed preventative measures can reduce avoidable rehospitalizations relating to seizure, new injuries, infection, and stroke. Current PTE practice strategies, which include post-acute antiepileptic medication only if there is a clinically expressed seizure after the first 24 hour[39,40]. New cases of PTE may develop years after injury, suggesting careful screening at long-term follow up may be warranted, particularly those known to be at greatest risk[41]. Similarly, those at elevated risk for re-injury[23,24,42] may require closer monitoring and physical therapy if new balance or motor impairments emerge[43,44].

Though empirical research informing specific care guidelines for those with chronic TBI are currently lacking, the results reported herein reinforce the need for, and may help inform the content of a chronic disease management model designed to improve long-term health for individuals with TBI. Understanding the risk factors associated with rehospitalization in a patient recovering from TBI can inform clinical decision-making and screening/surveillance practices to improve medical and functional outcomes and decrease the health care burden caused by rehospitalization.

Conclusion:

Severe and moderate TBI is gaining acceptance as a chronic health condition and there is an increased appreciation of the increased risk of potential medical and surgical complications years after a TBI. Thus, it is important to inform clinicians, families, and other stakeholders which patients might be the most vulnerable and at increased risk of developing such medical complications requiring rehospitalization. Our findings in the present study can inform improvements in the chronic care of patient recovering from moderate-severe TBI; including medical care, surveillance, prevention, lifestyle, and healthy behaviors to potentially reduce rehospitalization over the lifespan after the TBI.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Table 1.

Demographic and Clinical Variables by Rehospitalization at 1, 2, 5 and 10 years

	Rehospitalization 1-year post-injury			Rehospitalization 2 years post-injury			Rehospitalization 5 years post-injury			Rehospitalization 10 years post-injury		
Variables	**No**	**Yes**	**pvalue**	**No**	**Yes**	**pvalue**	**No**	**Yes**	**pvalue**	**No**	**Yes**	**pvalue**
n (%)	922 (76.6)	281 (23.4)	--	891 (78.9)	238 (21.1)	--	805 (79.2)	212 (20.9)	--	728 (81.4)	166 (18.6)	--
Measured at baseline												
Sex, n (%)			0.329			0.132			0.884			0.047 *
Female	222 (24.2)	75 (27.1)		221 (24.9)	70 (29.8)		220 (27.3)	59 (27.8)		174 (23.9)	52 (31.3)	
Male	696 (75.8)	202 (72.9)		665 (75.1)	165 (70.2)		585 (72.7)	153 (72.2)		554 (76.1)	114 (68.7)	
Race, n (%)			0.275			0.273			0.735			0.567
White	583 (63.6)	188 (67.1)		568 (64.0)	160 (67.8)		549 (68.2)	142 (67.0)		512 (70.3)	113 (68.1)	
Non-white	334 (36.4)	92 (32.9)		320 (36.0)	76 (32.2)		256 (31.8)	70 (33.0)		216 (29.7)	53 (31.9)	
Education, n (%)			0.682			0.687			0.283			0.261
Less than HS	149 (16.5)	43 (15.4)		156 (17.7)	44 (18.8)		147 (18.4)	32 (15.2)		168 (23.1)	45 (27.3)	
HS+	757 (83.6)	236 (84.6)		727 (82.3)	190 (81.2)		651 (81.6)	178 (84.8)		558 (76.9)	120 (72.7)	
Rehab payor source, n (%)			0.098			<0.001 *			0.008 *			0.034 *
Government insurance	320 (34.9)	111 (40.4)		296 (33.6)	130 (55.6)		259 (32.2)	89 (42.0)		202 (27.8)	60 (36.1)	
Other	597 (65.1)	164 (59.6)		585 (66.4)	104 (44.4)		545 (67.8)	123 (58.0)		524 (72.2)	106 (63.9)	
Length of stay during rehabilitation, Mean (SD)	23.1 (21.3)	29.2 (28.1)	<0.001 *	23.2 (20.8)	27.5 (30.9)	0.112	25.2 (26.4)	30.6 (32.2)	0.002 *	27.1 (24.3)	26.8 (26.5)	0.290
FIM Motor at Rehabilitation discharge, Mean (SD)	66.8 (16.8)	59.7 (20.6)	<0.001 *	67.5 (16.5)	61.1 (18.1)	<0.001 *	66.2 (17.0)	60.5 (18.8)	<0.001 *	67.7 (17.9)	64.6 (18.6)	0.015 *
FIM Cognitive at Rehabilitation Discharge, Mean (SD)	23.4 (6.5)	22.5 (7.4)	0.215	24.0 (6.3)	23.0 (7.1)	0.049 *	23.8 (6.4)	22.8 (7.4)	0.135	23.9 (6.4)	23.2 (6.3)	0.170
Cranial surgery status, n (%)	221 (24.1)	109 (39.6)	<0.001 *	225 (22.5)	70 (29.9)	0.177	218 (27.2)	65 (30.7)	0.310	196 (27.0)	39 (23.6)	0.372

	Rehospitalization 1-year post-injury			Rehospitalization 2 years post-injury			Rehospitalization 5 years post-injury			Rehospitalization 10 years post-injury		
Variables	**No**	**Yes**	**pvalue**	**No**	**Yes**	**pvalue**	**No**	**Yes**	**pvalue**	**No**	**Yes**	**pvalue**
Pre-index history of TBI, n (%)	197 (21.9)	63 (22.7)	0.764	232 (26.3)	47 (20.1)	0.049 *	245 (30.6)	74 (35.1)	0.216	197 (27.3)	36 (21.8)	0.147
Measured at prior TBIMS follow-up interview												
Problem substance use, n (%)	--	--	--	175 (22.0)	34 (16.1)	0.059	173 (23.1)	37 (19.4)	0.270	164 (26.7)	35 (24.3)	0.551
Post-index rehospitalization, n (%)	--	--	--	155 (19.0)	103 (47.9)	<0.001 *	118 (15.3)	72 (36.7)	<0.001 *	93 (14.4)	59 (39.2)	<0.001 *
PART summary, Mean (SD)	--	--	--	1.7 (0.7)	1.4 (0.7)	<0.001 *	1.8 (0.7)	1.6 (0.7)	<0.001 *	1.8 (0.7)	1.6 (0.7)	<0.001 *
Driving independence, n (%)	--	--	--	363 (45.8)	57 (27.3)	<0.001 *	392 (52.7)	74 (39.2)	<0.001 *	376 (59.9)	83 (56.1)	0.399
Measured at the same follow-up interview as rehospitalization variable												
Age, n (%)			0.046 *			<0.001 *			<0.001 *			<0.001 *
16–29	271 (29.6)	73 (26.0)		281 (31.6)	40 (16.9)		195 (24.2)	40 (18.9)		103 (14.2)	8 (4.8)	
30–49	247 (26.9)	71 (25.3)		247 (27.8)	69 (29.1)		280 (35.8)	53 (25.0)		358 (49.2)	74 (44.6)	
50–64	214 (23.3)	58 (20.6)		189 (21.3)	58 (24.5)		176 (21.9)	56 (26.4)		173 (23.8)	45 (27.1)	
65+	185 (20.2)	79 (28.1)		171 (19.3)	70 (29.5)		154 (19.1)	63 (29.7)		94 (12.9)	39 (23.5)	
Seizures in the past year, n (%)	65 (7.1)	84 (30.1)	<0.001 *	78 (8.9)	54 (23.0)	<0.001 *	55 (6.8)	49 (23.6)	<0.001 *	41 (5.7)	38 (23.0)	<0.001 *
Total number of medical comorbidities, n (%)			<0.001 *			<0.001 *			<0.001 *			<0.001 *
0–1	533 (58.9)	100 (35.7)		484 (55.3)	70 (29.5)		465 (58.4)	73 (34.4)		431 (60.0)	49 (29.5)	
2+	372 (41.1)	180 (64.3)		391 (44.7)	167 (70.5)		331 (41.6)	139 (65.6)		287 (40.0)	117 (70.5)	
Total number of mental health comorbidities, n (%)			0.021 *			<0.001 *			<0.001 *			0.011 *
0–1	491 (54.7)	129 (46.7)		460 (52.9)	86 (36.9)		430 (54.2)	82 (39.1)		380 (53.2)	69 (42.1)	
2+	407 (45.3)	147 (53.3)		410 (47.1)	147 (63.1)		363 (45.8)	128 (60.9)		335 (46.9)	95 (57.9)	

* statistically significant at α=0.05

Table 2.

Top 10 Reasons for Rehospitalization at 1, 2, 5, and 10 years post-TBI

	Year 1		Year 2		Year 5		Year 10	
Rank	**Reason for Rehospitalization**	**Rate per 1000 persons with TBI**	**Reason for Rehospitalization**	**Rate per 1000 persons with TBI**	**Reason for Rehospitalization**	**Rate per 1000 persons with TBI**	**Reason for Rehospitalization**	**Rate per 1000 persons with TBI**
1	6.4. Epilepsy; convulsions	32.4	6.4. Epilepsy; convulsions	25.7	6.4. Epilepsy; convulsions	23.6	16.2. Fractures; treatment of fractures or dislocation	19.0
2	16.4. Intracranial injury; craniotomy or craniectomy procedure	15.0	16.2. Fractures; treatment of fractures or dislocation	22.1	16.2. Fractures; treatment of fractures or dislocation	16.7	6.4. Epilepsy; convulsions	17.9
3	7.2. Diseases of the heart; heart procedures	14.1	7.2. Diseases of the heart; heart procedures	15.9	7.2. Diseases of the heart; heart procedures	15.7	16.12. Other injuries and conditions due to external causes	12.3
4	1.1 Bacterial infection	13.3	1.1. Bacterial infection	15.1	10.1. Diseases of the urinary system; operations on the urinary system	11.8	7.2. Diseases of the heart; heart procedures	7.8
5	16.2. Fractures; treatment of fractures or dislocation	10.8	10.1. Diseases of the urinary system; operations on the urinary system	15.1	1.1. Bacterial infection	9.8	9.6. Lower gastrointestinal disorders; lower gastrointestinal procedures	7.8
6	17.1. Symptoms; signs; ill-defined conditions	10.0	16.4. Intracranial injury; craniotomy or craniectomy procedure	11.5	8.1. Respiratory infections	8.8	10.1. Diseases of the urinary system; operations on the urinary system	7.8
7	10.1. Diseases of the urinary system; operations on the urinary system	9.1	16.12 Other injuries and conditions due to external causes	9.7	5.8. Mood disorders; electroconvulsive therapy	6.9	16.1. Joint disorders and dislocations; trauma-related	6.7
8	13.2. Non-traumatic joint disorders; arthroplasty; other	9.1	17.1. Symptoms; signs; ill-defined conditions	7.1	16.12. Other injuries and conditions due to external causes	6.9	8.1. Respiratory infections	5.6
9	17.2 Factors influencing health care (rehabilitation care, medical examination, other aftercare)	9.1	7.3. Cerebrovascular disease/ stroke; endarterectomy; vessel of head and neck	6.2	7.3. Cerebrovascular disease/ stroke; endarterectomy; vessel of head and neck	5.9	16.4. Intracranial injury; craniotomy or craniectomy procedure	5.6
10	7.3. Cerebrovascular disease/ stroke; endarterectomy; vessel of head and neck	7.5	8.1. Respiratory infections	6.2	16.1. Joint disorders and dislocations; trauma-related	5.9	5.2 Anxiety disorders	4.5

Note: For ties in rate, reasons for rehospitalization are listed in the ascending order of codes

Table 3.

Multivariable Logistic Regression Model for Predictors of Likelihood of Rehospitalization at 1, 2, 5, and 10 years post-TBI

	Rehospitalization 1-year post-injury (n=1113)		**Rehospitalization 2 years post-injury (n=907)**		**Rehospitalization 5 years post-injury (n=874)**		**Rehospitalization 10-year post-injury (n=709)**	
Variables	**OR (95% CI)**	**pvalue**	**OR (95% CI)**	**pvalue**	**OR (95% CI)**	**pvalue**	**OR (95% CI)**	**pvalue**
Measured at baseline								
Sex								
Male (ref)	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
Female	1.19 (0.83, 1.69)	0.341	0.92 (0.61, 1.39)	0.704	0.79 (0.53, 1.18)	0.254	1.28 (0.80, 2.05)	0.298
Race								
White (ref)	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
Non-white	0.79 (0.56, 1.12)	0.183	0.71 (0.45, 1.10)	0.125	1.30 (0.86, 1.96)	0.220	0.93 (0.57, 1.53)	0.776
Education								
Less than HS (ref)	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
HS+	0.96 (0.62, 1.50)	0.854	0.90 (0.54, 1.50)	0.682	1.48 (0.88, 2.49)	0.145	0.81 (0.47, 1.39)	0.447
Rehab payor source								
Government insurance (ref)	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
Other	1.03 (0.73, 1.45)	0.858	0.56 (0.38, 0.83)	0.004*	0.90 (0.61, 1.34)	0.609	0.94 (0.58, 1.51)	0.794
Length of stay during rehabilitation	1.01 (1.00, 1.01)	0.187	1.00 (0.99, 1.01)	0.968	1.00 (0.99, 1.01)	0.807	1.00 (0.99, 1.01)	0.940
FIM Motor at Rehabilitation discharge	0.98 (0.97, 0.99)	<0.001*	0.99 (0.97, 0.99)	0.027*	0.98 (0.97, 0.99)	0.009*	0.99 (0.98, 1.01)	0.235
FIM Cognitive at Rehabilitation Discharge	1.04 (1.01, 1.07)	0.011*	1.02 (0.98, 1.05)	0.366	1.02 (0.99, 1.06)	0.149	0.99 (0.96, 1.03)	0.578
Cranial surgery status								
No cranial surgery (ref)	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
Craniotomy and/or Craniectomy	2.29 (1.64, 3.22)	<0.001	0.83 (0.54, 1.28)	0.400	0.90 (0.59, 1.37)	0.616	0.89 (0.54, 1.45)	0.635

	Rehospitalization 1-year post-injury (n=1113)		Rehospitalization 2 years post-injury (n=907)		Rehospitalization 5 years post-injury (n=874)		Rehospitalization 10-year post-injury (n=709)	
Variables	**OR (95% CI)**	**pvalue**	**OR (95% CI)**	**pvalue**	**OR (95% CI)**	**pvalue**	**OR (95% CI)**	**pvalue**
Pre-index history of TBI (yes vs. no)	0.94 (0.64, 1.36)	0.726	0.53 (0.33, 0.83)	0.006*	1.20 (0.81, 1.76)	0.360	0.69 (0.42, 1.12)	0.133
Measured at prior TBIMS follow-up interview								
Problem substance use (yes vs. no)	--	--	0.69 (0.41, 1.17)	0.165	0.80 (0.50, 1.28)	0.353	1.17 (0.70, 1.97)	0.551
Post-index rehospitalization (yes vs. no)	--	--	3.24 (2.20, 4.78)	<0.001*	2.24 (1.49, 3.38)	0.001*	3.25 (2.07, 5.10)	<0.001*
PART summary	--	--	0.93 (0.66, 1.31)	0.679	1.01 (0.73, 1.40)	0.963	0.89 (0.62, 1.29)	0.542
Driving independence (yes vs. no)	--	--	0.94 (0.59, 1.52)	0.814	0.89 (0.57, 1.38)	0.596	1.31 (0.79, 2.17)	0.301
Measured at the same follow-up interview as rehospitalization variable								
Age								
16–29 (ref)	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
30–49	0.87 (0.56, 1.34)	0.517	2.12 (1.21, 3.73)	0.009*	0.71 (0.41, 1.21)	0.203	2.42 (0.97, 6.02)	0.057
50–64	0.83 (0.52, 1.32)	0.426	1.91 (1.04, 3.51)	0.038*	1.30 (0.74, 2.28)	0.361	2.57 (0.97, 6.80)	0.057
65+	1.01 (0.60, 1.68)	0.983	1.79 (0.92, 3.48)	0.085	1.59 (0.87, 2.89)	0.131	4.34 (1.58, 11.93)	0.004*
Seizures in the past year (yes vs. no)	5.10 (3.40, 7.64)	<0.001*	3.00 (1.77, 5.06)	<0.001*	3.74 (2.22, 6.31)	<0.001*	3.64 (1.98, 6.69)	<0.001*
Total number of medical comorbidities (2+ vs. 1 or 0)	2.89 (2.01, 4.15)	<0.001*	1.69 (1.01, 2.61)	0.017*	1.61 (1.06, 2.43)	0.025*	2.10 (1.31, 3.39)	0.002*
Total number of mental health comorbidities (1+ vs. 0)	1.19 (0.86, 1.64)	0.293	1.67 (1.13, 2.47)	0.010*	1.57 (1.06, 2.30)	0.023*	1.13 (0.72, 1.78)	0.595
Total Model AUC:	0.761		0.782		0.739		0.764	

*statistically significant at α=0.05