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Rehospitalization During the 9-Months Following Inpatient Rehabilitation for Traumatic Brain Injury

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Abstract

Objective—To investigate frequency of, causes for, and factors associated with acute rehospitalization following discharge from inpatient rehabilitation during the 9-months after traumatic brain injury (TBI).

Design—Multi-center observational cohort.

Setting—Community.

Participants—1,850 individuals with TBI admitted for inpatient rehabilitation.

Interventions—Not applicable.

Main Outcome Measure(s)—Occurrences of proxy or self-report of post-rehabilitation acute care rehospitalization, and length of and causes for rehospitalizations.

Results—510 participants (28%) had experienced 775 acute rehospitalizations. All experienced 1 admission (510 participants; 66%), while 154 (20%) had 2 admissions, 60 (8%) had 3, 23 (3%) had 4, 27 had between 5 and 11, and 1 had 12. The most common rehospitalization causes were:

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infection (15%), neurologic issues (13%), neurosurgical procedures (11%), injury (7%), psychiatric (7%), and orthopedic (7%). Mean days from rehabilitation discharge to first rehospitalization was 113 days. Mean rehospitalization duration was 6.5 days. Logistic regression revealed increasing age, history of seizures prior to injury or during acute care or rehabilitation, history of previous brain injuries, and non-brain injury medical severity increased the risk of rehospitalization. Injury etiology of motor vehicular crash and high motor functioning at discharge decreased rehospitalization risk.

Conclusion(s)—Approximately 28% of TBI patients were rehospitalized within 9-months of TBI rehabilitation discharge due to a wide variety of medical and surgical reasons. Future research should evaluate if some of these occurrences may be preventable (such as infections, injuries, and psychiatric readmissions), and should evaluate the extent that persons at risk may benefit from additional screening, surveillance, and treatment protocols.

Keywords

Brain injuries; Rehabilitation; Hospitalization; Patient readmission; Comorbidity

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In the United States and Canada, there has been increasing concern about the costs and impact of acute care hospitalization soon after hospital discharge. In a review of general *acute* hospital readmission studies, [1] 9-48% of readmissions in the United States and 9-59% in Canada were considered preventable. These readmissions are thought to have resulted from inadequate treatment for the originating medical problem, instability at discharge, and inadequate post-discharge care. It is thought that better identification of those most likely to return to an acute care hospital within a short period and improvement of the care they receive after discharge may reduce these admissions. [2] Readmission to an acute care hospital within 30 days of discharge varies greatly across hospitals in the United States, with 11.4% - 18.1% among medical discharges and 7.6% -18.3% surgical discharges at 306 hospital referral regions. [3] In Canada, roughly 8.5% of all inpatients are readmitted to an acute care hospital within 30 days of discharge. [4] The 181,551 readmissions over the 11-month study period carried an estimated cost of $1.8 billion or 11% of all the money spent on inpatient care, not including physician fees for services. In addition to the increased financial burden, rehospitalizations may disrupt community integration, and increase health risks. [1]

Corollaries between rehospitalization following *acute care discharge* may exist with rehospitalization following *inpatient rehabilitation discharge*. Efforts to reduce rehospitalization following acute rehabilitation will require data to determine common modifiable triggers for readmission. However, among individuals with traumatic brain injury (TBI), there are limited data about rehospitalization rates, causes, and risk factors. Such information may allow clinicians and hospital administrators to design systems of care to better prevent rehospitalizations, and improve health following TBI.

There has been increasing demand on acute rehabilitation providers in the United States and Canada to more efficiently and effectively manage all aspects of medical care, during and after inpatient rehabilitation. Over recent decades, acute rehabilitation length of stay (RLOS) has progressively shortened in duration,[5] while medical acuity and complexity has progressively increased.[6,7] Furthermore, in 2002 the United States implemented the

Inpatient Rehabilitation Facility Prospective Payment System in the post-acute care settings, which based reimbursement on case-mix groups (i.e., higher payment for higher acuity), incentivized inpatient rehabilitation facilities to select admission of more severe patients.[8-10] Subsequent passage of the Affordable Care Act (ACA) [6] has aligned incentives with markers of quality care, such as rehospitalization soon after discharge. In accordance with the ACA, the Centers for Medicare and Medicaid Services (CMS, a primary payer for acute and rehabilitation services in the United States) has introduced penalties for rehospitalization within 30 days from acute care discharge for some diagnoses. CMS also has released "draft" criteria for a quality measure of all-cause rehospitalization within 30 days following rehabilitation discharge. These efforts have enhanced the attention by many rehabilitation providers to reduce rehospitalizations during and after inpatient rehabilitation.[11,12] The advent of performance-based bundled payment systems resulting from the ACA may further impact medical care decisions related to rehabilitation service delivery in four primary ways: (1) shifting patients to the most appropriate and cost-effective rehabilitation setting within an episode of care; (2) providing comprehensive rehabilitation treatment within a compressed timeframe to produce functional gains; (3) minimizing rehospitalization during inpatient rehabilitation; and (4) surveilling current and emergent medical conditions to prevent rehospitalization following inpatient rehabilitation discharge in both the short- and long-term.

Harrison-Felix and colleagues found that in the years following inpatient rehabilitation, individuals with TBI In comparison to the general population, death is increased[13] 37-fold due to seizures, 12-fold due to septicemia, 4-fold due to pneumonia, and 3-fold due to respiratory conditions, digestive conditions, and external causes of injury. Four TBI registry studies have shown that external injury is a leading cause of death (18%-20%) in the year following discharge.[13-1613-16] Re-injury also causes high rates of emergency room visits and hospitalizations. In one study, 32% of a sample of 504 TBI participants had 228 emergency room visits or hospitalizations due to unintentional injuries within a wide range of follow up from 3-months to several years following discharge.[17]

Three studies using data collected from the TBI Model Systems (TBIMS) registry which utilizes annual follow-up interviews have focused on incidence and causes for rehospitalization following TBI rehabilitation discharge. Cifu et al. [18] found that the annual rehospitalization incidence among 665 individuals with TBI in years 1, 2, and 3 following injury ranged from 20 to 23%. Of the first year rehospitalizations, 44% were classified as "orthopedic or reconstructive", which in that study included removal of hardware, cranioplasty, fracture repair, and reconstructive surgeries. Orthopedic and reconstructive surgery remained the most common rehospitalization reason for years 2 and 3. Infections accounted for 8-17% of the rehospitalizations across the 3-year period. Year 1 infection included hardware infections (36%), meningitis (18%), pneumonia (18%), and gastrointestinal infections (18%). Seizures and psychiatric disorders accounted for 6 to 15% of the rehospitalizations, with the majority of these incidences occurring in Years 2 and 3. Rehospitalization for rehabilitation accounted for approximately 4% of all readmissions during the first year and none thereafter. Rehospitalization occurrence and etiology did not have a statistical association with demographics, injury severity, payer source for rehabilitation, concurrent injuries, acute care and rehabilitation length of stays, discharge

Functional Assessment Measure, and discharge residence. Similarly, Marwitz et al [19] found a 23% rehospitalization rate during the first year after inpatient rehabilitation for 895 individuals with TBI, with reasons including orthopedic/reconstructive (25%), general health maintenance (21%), seizures (13%), psychiatric (12%), infection (10%), neurologic (6%), and rehabilitation (3%), with 10% of unknown cause. Elective rehospitalizations accounted for one-third of the admissions. As with Cifu et al.[18], no relationship was found between rehospitalization and injury characteristics, demographics, functional status, or lengths of stay though both studies are notably small and lack sufficient power to fully assess this issue. More recently, Nakase-Richardson and colleagues (2013) [20] reported a 20.6% incidence of rehospitalizations during the year following TBI rehabilitation for 9,028 individuals. Persons with more severe levels of cognitive impairment at the time of inpatient rehabilitation admission had higher rates of post-discharge rehospitalization with a two-fold increase in rehospitalization among patients with disorders of consciousness at rehabilitation admission relative to those with moderate or severe TBI without command following at rehabilitation admission. This paper focused on the rehospitalizations for those with disordered consciousness. Reasons for rehospitalization were grossly similar to those reported in other TBIMS studies.

With increased awareness of the cost of rehospitalzations and the need to reduce them, there is great need for large TBI cohort evidence that may inform care and process improvement efforts. This large prospective, longitudinal study reports the incidence, causes, and factors associated with rehospitalization following rehabilitation discharge following TBI inpatient rehabilitation. Specifically, this study describes the acute medical and psychiatric rehospitalizations occurring during the first 9 months following rehabilitation discharge for individuals with TBI by examining: 1) the number of individuals rehospitalized, 2) the number of rehospitalizations, 3) the reasons for rehospitalization, 4) characterization of rehospitalizations during the first month after rehabilitation discharge, and 5) the association of rehospitalization with patient characteristics (e.g., demographics, injury characteristics, severity of illness, and function) and clinical practice features (such as medication prescription). The large sample size and comprehensive characterization of participants and treatments received provide a more in-depth assessment of rehospitalization following TBI inpatient rehabilitation discharge than has been possible previously.

METHODS

Study Participants

2,130 patients were enrolled between October 2008 and September 2011 in this multi-center practice-based evidence (PBE) study of the TBI inpatient rehabilitation process referred to as the TBI-PBE project.[21] The project took place at 9 inpatient rehabilitation facilities in the United States and 1 in Canada. Each site received Institutional Review Board approval. Participants were 14 years of age or older and admitted to the facility's adult brain injury inpatient rehabilitation unit for initial rehabilitation following TBI. Patients (or their parent/ guardian) provided informed consent. For this study on rehospitalization after inpatient rehabilitation we excluded 280 participants who did not complete any of the follow up interviews to yield a final sample of 1,850 participants. The 280 participants with follow up

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interviews not completed included 149 that did not consent to the follow-up component of the study, 41 who were deceased or incarcerated, and 90 who were lost to any follow up.

Participant inpatient rehabilitation medical records were abstracted for details about the treatments delivered, medical complications, function, and other outcome measures. Following discharge from inpatient rehabilitation, study research staff contacted participants at 3 and 9 months post-discharge for a comprehensive interview about their function, additional medical and rehabilitation treatment received, medical complications, and function following rehabilitation discharge. Eighty-nine percent of the 1,850 included participants completed a 9-month post-rehabilitation discharge interview. Interviews occurred at a mean of 309 days (SD 43) from discharge. Fifty-one (3%) participants had died or were incarcerated. For these participants, rehospitalization data came from the 3-month post-rehabilitation discharge interview resulting in a mean of 100 days (SD 30) from discharge to interview. The remaining 144 (8%) participants were lost to follow up at 9 months for whom the rehospitalization data came from the 3-month interview with a mean of 114 days (SD 32) from discharge to interview. The introductory paper to this series of articles gives additional information on the TBI-PBE project design, including the PBE research methodology, inclusion criteria, data sources, and analysis plan. [21]

Patient, Injury, and Functional Predictor Variables

Patient, injury, and medical characteristics were abstracted from medical records including gender, race, age at injury, education level, marital status, employment status, medical payer, cause of injury, number of brain injuries prior to the current injury, pre-injury illicit drug use, alcohol use, and time from injury to rehabilitation admission. The Comprehensive Severity Index (CSI®), the study's principal illness severity measure, was used to score the extent of deviation from normal status for each medical complication and comorbidity present during the first 3 days after admission, the last 3 days before discharge, and over the entire rehabilitation stay.[21,22] Possible CSI scores range from 0 to 336 with higher scores denoting greater medical severity. A modification of CSI was also used that separated severity of brain injury (called the brain injury component of CSI) from severity of illness of all other injuries, complications, and comorbidities (called the non-brain injury component of CSI). [21]

Data were collected regarding several procedures or medical conditions that occurred prior to and during acute rehabilitation stay, including urinary tract infection, seizure, pneumonia, and agitation. The Agitated Behavior Scale (ABS) was administered every shift for the first three days of the rehabilitation stay and thereafter until the ABS score had been <21 for three consecutive days. Medications received during inpatient rehabilitation were recorded, including antipsychotic medications. Readmissions to acute care during acute inpatient rehabilitation, time from injury to rehabilitation, and RLOS served as additional proxy measures of severity. RLOS was calculated with exclusion of any days during which the rehabilitation stay was interrupted for readmission to acute care. The patient's burden of care and functional ability for motor and cognitive activities at rehabilitation admission was assessed by the Functional Independence Measure (FIM®). All FIM Cognitive and Motor scale scores were Rasch-transformed to 0-100 scores on a ratio scale as described in prior publications.[23] Lastly, type of rehabilitation discharge disposition location was noted.

Definition of Rehospitalization

During the follow up interviews, participants were asked "Since your discharge from the rehabilitation center [or: since last interview], have you stayed overnight in a hospital because you were ill or injured? If YES, the participant was asked: "For each admission can you tell me... what was the approximate date of each admission, what was the reason for your admission, and how many days did you spend in the hospital?" All positive responses as recorded free-style by the interviewer were considered to represent a rehospitalization with the exception of hospital-based polysomnography lab sleep studies. Visits to the Emergency Department without admission were not counted as a rehospitalization. Investigators reviewed the recorded reasons for rehospitalization and assigned them to categories that best represented the cause for the rehospitalization. See the digital supplemental data [provide link to SDC table here] for a complete breakdown of rehospitalization causes. In order to avoid counting an episode more than once when more than one reason was provided, clinical judgment and available information were used to reach agreement on the primary reason for each hospitalization. Additionally, dates of rehospitalization were recorded and reviewed for duplication. In addition to studying rehospitalizations that occur anytime during follow up interval, we also looked at those occurring withn the first 30 days since discharge as a means of highlighting those that may be the most amenable to prevention

Data analysis

Rehospitalizations are described as to probable cause and associated factors: demographic and pre-injury characteristics, injury and medical issues during the acute care and inpatient rehabilitation stays, and outcome at rehabilitation discharge. For discrete variables, we used the chi-square test to determine significance of associations. For continuous variables we used t-tests or analysis of variance (ANOVA). A two-sided p value <0.05 was considered statistically significant. When data were missing, one or more adjustments were made depending on the variable and its intended use in analyses. Sometimes missing values were categorized as "unknown" and were included in analysis as a dummy variable; other times patients with missing data were removed from analyses.

Logistic regression analyses were used for the multivariable analyses of whether patients experienced one or more rehospitalizations. Variables available at the time of rehabilitation hospital discharge (e.g., demographic, pre-injury, injury, medical, and functional data described earlier) were identified as potential predictors. Five models were created to identify factors associated with rehospitalization for each of the following causes: 1) any reason, 2) infection, 3) injury, 4) psychiatric, and 5) seizure. Patients with each cause of rehospitalization were compared, in the models, to the 1340 patients who were never rehospitalized.

Stepwise selection was used to identify parsimonious models, with factors entering or leaving each model based on their lack of association with rehospitalization at $p>0.05$.

Variables allowed to enter into these models included: age at the time of injury, gender, race, pre-injury illicit drug use, pre-injury alcohol use, inpatient rehabilitation medical complications of urinary tract infection, seizure, and pneumonia, cause of the TBI, occurrence of rehospitalization during inpatient rehabilitation, RLOS, time from injury to rehabilitation admission, maximum non-brain injury CSI, maximum brain injury CSI, Rasch-adjusted FIM Motor and Cognitive scores at time of rehabilitation discharge, average of the three highest ABS scores during inpatient rehabilitation, number of previous brain injuries, type of rehabilitation discharge location (home or institutional setting), and administration of a benzodiazepine or an antipsychotic medication during the last two days of inpatient rehabilitation.

Model performance was evaluated using the area under the receiver operating characteristic curve (c statistic) and a rescaled R^2.[24] The reference category for each of the construct independent variables are all of the categories that do not enter significantly into the model. Analyses were performed using SAS version 9.2 (SAS Institute, Inc., Cary, NC).

RESULTS

Patient characteristics

Table 1 describes the characteristics of those participants who did and did not experience rehospitalization. The sample was 72% male, 76% white, 36% married, and 51% employed at the time of injury. Average age of the sample was 44 years. The most common cause of injury was vehicular crash (57%), followed by fall or being hit by flying object (31%), violence (7%), and sports (2%). Mean RLOS was 27 days (SD 20). The mean ‘raw’ FIM Motor score at admission was 34.3 (SD 19.5) and the mean FIM Cognitive score was 14.7 (SD 7.2). The mean time from injury to rehabilitation admission was 30 days (SD 36).

Rehospitalizations: Incidence, Causes, and Time of Events

Following rehabilitation discharge, 510 participants (28%) experienced rehospitalization for a total of 775 episodes. Of the participants rehospitalized, all experienced 1 rehospitalization (510), while 154 had 2 rehospitalizations, 60 had 3 rehospitalizations, 23 had 4 rehospitalizations, 27 had between 5 and 11, and 1 had 12 rehospitalizations.

The frequency of rehospitalization by primary cause is summarized in table 2 with additional details provided in the table published as supplemental digital content [provide link to SDC table here]. These tables also detail the frequency by cause for rehospitalization that occurred within the first 30 days after inpatient rehabilitation discharge. The most common rehospitalization causes were: infectious (15%), neurologic (13%), neurosurgical (11%), unknown (10%), psychiatric (7%), injury (7%), and orthopedic (7%). Of the 120 rehospitalizations for infection, the source/location of the infection could not be determined through the study participant interview for 45%. For the remaining rehospitalizations for infection, the source was most commonly urinary tract infection (18%) and pneumonia (17%). The 99 rehospitalizations for neurologic cause were primarily due to seizure (64%), and of 84 neurosurgical hospitalizations 60% were due to cranioplasty. Injuries requiring rehospitalization were predominantly due to falls (51%) and medication toxicity or side effects (18%).

Estimated mean time from *injury to first rehospitalization* was 174 days (SD 105, Median 149). Mean days from rehabilitation discharge to first rehospitalization was 113 days (SD 97, Median 83) with a mean duration of rehospitalization of 6.5 days (SD 12, Median 3). For *all rehospitalization episodes*, estimated mean time from injury to rehospitalization was 189 days (SD 107, Median 169). Mean days from rehabilitation discharge to all rehospitalizations was 126 days (SD 98, Median 104).

Comparing the reasons for rehospitalization during the first month after rehabilitation discharge to the composition of reasons during the entire post-discharge period, rehospitalization for orthopedic reasons were slightly less common and rehospitalization due to injury slightly more common during the first month in the community. Otherwise, rehospitalization reasons during the first month after rehabilitation discharge were similar to those across the entire time frame with rehospitalizations during both periods commonly occurring due to infection, injury, neurosurgery, and neurologic.

Predictors of Rehospitalizations

Regression analyses, as summarized in tables 3a and 3b, indicated several variables were associated with experiencing one or more rehospitalizations: older age at injury, number of previous brain injuries, greater non-brain injury severity of illness score, and history of seizure pre-injury or seizure during inpatient rehabilitation. Rehospitalization was less likely when cause of injury was a motor vehicle crash and for patients with higher Rasch-adjusted FIM Motor score at the time of rehabilitation discharge. A c statistic of 0.66 indicated adequate model performance.

Rehospitalization for infection was more likely when a post-injury urinary tract infection occurred before or during inpatient rehabilitation, the TBI was caused by a fall, and with higher non-brain injury severity of illness score. Rehospitalization for infection was less likely for patients with higher Rasch-adjusted FIM Motor score at the time of rehabilitation discharge. The c statistic for rehospitalization due to infection was 0.78.

Rehospitalization for re-injury was more likely if older at injury, post-injury urinary tract infection occurrence before or during inpatient rehabilitation, longer time from injury to rehabilitation admission, greater non-brain injury severity of illness, and larger number of previous brain injuries. Rehospitalization due to injury was less likely with longer RLOS. The c statistic of 0.82 indicated good model performance.

Variables that predicted greater likelihood of rehospitalization for psychiatric reasons included history of seizure or seizure occurrence during inpatient rehabilitation, and administration of an antipsychotic medication during the last two days of inpatient rehabilitation. Psychiatric rehospitalization was less likely with males and patients with higher Rasch-adjusted FIM Motor score at the time of rehabilitation discharge. The c statistic was 0.70.

Seizure requiring rehospitalization was more likely if patients had post-injury pneumonia or seizure before or during inpatient rehabilitation, but was less likely when cause of injury was motor vehicle crash and for patients with higher Rasch-adjusted FIM Motor score at the time of rehabilitation discharge. The c statistic of 0.80 indicated good model performance.

DISCUSSION

Reducing readmission rates following TBI is a multi-faceted issue that requires actions from all levels of the health care system. This study provides information about patient-level factors that may contribute to readmission rates The primary aim of this study was to improve the understanding of rehospitalizations during 9 months after TBI inpatient rehabilitation discharge, the reasons for readmissions, and the factors that may place patients at risk. The findings indicated that 28% of patients were rehospitalized. Multiple rehospitalizations occurred for 154 (8%) of all study participants. Of 775 rehospitalizations, 117 (15%) occurred in the first month after rehabilitation discharge. The most common rehospitalization causes were: infection (15%), neurologic (13%), neurosurgical (11%), injury (7%), psychiatric (7%), and orthopedic (7%). Thirteen additional categories of medical conditions accounted for another 30% of rehospitalizations. Causes of rehospitalizations during the first month after discharge were generally similar to those that occurred across the full 9 months surveillance time frame.

The rates of rehospitalization following inpatient rehabilitation discharge in the first nine months post-TBI were slightly higher, 28% than the 21% to 23% reported in the three TBIMS registry cohorts. [16-18] More frequent surveying of participants in the follow-up window and recording of rehospitalizations due to new injury may at least partially account for the higher reported rates in this study. While categorization of reasons for rehospitalizations differed somewhat between this study and the TBIMS studies, these findings suggest fairly similar rates of rehospitalizations for seizures, psychiatric disturbances, infections, and neurologic issues (other than seizures). This study found fewer reported rehospitalizations for orthopedic/reconstructive issues (7%) than the TBIMS cohort (25%). However, some of the cases that were classified as injury in this study may have been counted as orthopedic in these TBIMS studies. We may have underreported hospitalizations that were planned, such as elective surgeries, reconstructive surgery, or cranioplasty, as we asked if the participant stayed overnight in a hospital because of “illness or injury”. Of note, three of the ten TBI-PBE sites were also TBIMS sites, though TBIMS eligibility criteria are narrower, requiring that acute care was received within the TBIMS of care.

This study significantly contributes to the research literature on specific conditions documented as reasons for rehospitalization. The documentation of 19 distinct major categories with no single major category accounting for more than 15% of rehospitalizations and an additional 145 specific rehospitalization reasons grouped under these major categories (see Table 2 and the supplemental digital content) provides a clearer picture of the very broad scope of medical and behavioral issues that patients and family caregivers potentially face upon rehabilitation discharge. These data also speak to the high demand placed on inpatient rehabilitation centers to anticipate, monitor, and provide preventative interventions and/or early treatment for such a broad set of issues. 15% of rehospitalizations occurred in the first 30 days following discharge.

The ACA has led to increased inpatient rehabilitation center accountability for patient rehospitalizations after discharge. Our findings suggest that evolving bundled care payment initiatives for TBI service delivery must give careful consideration to: (1) the expertise required of persons evaluating and monitoring these broad and complex medical and behavioral issues; (2) defining when an episode of care truly ends for this population; (3) building into the bundled payment appropriate funding tiers commensurate to the level of clinical expertise and the duration of surveillance, monitoring, and treatments required; and (4) the extent medical conditions following brain injury may be anticipated and prevented.

Another unique contribution to the literature is this study's preliminary identification of potential risk factors for rehospitalizations. Risk factors identified in the overall model and at least one other model included: older at time of injury, experienced seizure before or during rehabilitation, or urinary tract infection (during acute care or rehabilitation), lower FIM Motor or Cognitive score at the time of rehabilitation admission, more severe non-brain injury specific illnesses during inpatient rehabilitation, and history of one or more previous brain injuries. Conversely, those who were discharged with higher levels of physical independence had a reduced risk of rehospitalization. Perhaps it is not surprising that rehospitalization for any reason and re-injury were related to older age, which is often accompanied by greater comorbidity and high fall risk, while age did not emerge as a significant predictor of rehospitalization due to psychiatric need, seizure, or infection. In addition, the non-brain injury component of Maximum CSI was significant in several models, and may have accounted for some of the effect that older age generally has on comorbidities and their severity.

Some risk factors identified in this study might be useful in the development and testing of measures to prevent these rehospitalizations, and determine if such preventive efforts would reduce associated consequences such as death. Individuals with TBI have much higher risk of death due to seizure, infection, and re-injury.[13] In this study, history of seizure before or during rehabilitation predicted later rehospitalization for seizure. Thus, models for the care of chronic brain injury[25] might benefit from incorporating such a marker as a trigger for greater surveillance. Similarly, it seems reasonable that administration of antipsychotic medication during the last days of rehabilitation might be a useful marker of subsequent psychiatric hospitalization.

Future Clinical and Research Directions

Healthcare savings may be realized by reducing those rehospitalizations. Clinical databases should be utilized to monitor readmissions, and thereby provide a tool for benchmarking and process improvement. Research to further assess the factors contributing to these rehospitalizations is warranted to understand if some are preventable, and if so which ones, and how. Future research in this population should examine post-discharge factors such as the amount and type of inpatient rehabilitation surveillance provided, family caregiver knowledge and characteristics, compliance with treatments, healthcare access, and healthcare services sought and received in order to identify factors that modify risk. This evidence could be used to inform the development of evidence-based, risk stratified, prevention and intervention protocols when warranted as well as experimental protocols aimed at increasing dose/intensity of existing interventions and new interventions to reduce risk of rehospitalizations. Implementing interventions before and after discharge such as focused patient education, discharge planning, proactive follow up calls, supported self-management, and physician follow-up may reduce readmission rates. Possible post discharge interventions include follow-up phone calls, patient hotlines and timely clinical follow-up.

Study Limitations

The TBI-PBE Project took place at specialized centers for TBI rehabilitation, and thus, specific findings regarding reasons for rehospitalization may not generalize to all rehabilitation facilities. The study relied on self-report from people with TBI or their proxy to determine the occurrence of, approximate dates of, and reasons for rehospitalization. Thus, the rehospitalization reasons recorded were based on the informant's awareness and understanding of the reason for rehospitalization rather than actual medical documentation. Unless they specifically reported it, we would not have known if surgery was performed. Data about whether the admission was planned or unplanned was not collected. Thus, while many of the readmissions could be attributed to conditions that were directly related to the initial trauma or its complications, such as cranioplasty, for other neurosurgical procedures, orthopedic surgeries, seizures, tracheal stenosis and feeding tube complications, we cannot definitively make these determinations. The types and duration of signs, symptoms, and treatments leading up to the rehospitalization were not studied. The risk factors identified in this sample are best interpreted as preliminary evidence that may inform future studies of rehospitalization; these risk factors should not be used to predict the occurrence of rehospitalization in clinical settings.

Conclusion

Approximately 28% of the TBI patients in this study were rehospitalized during the first 9 months following rehabilitation discharge for a wide variety of medical and surgical reasons. Many of these occurrences such as infections, injuries, and psychiatric emergencies, may be preventable. Through this study, we have identified several risk factors for rehospitalization. An improved understanding of the factors may allow increased collaboration among leaders of different health system components to decrease readmissions. Future research should evaluate the extent to which persons at risk may benefit from additional screening, surveillance, and treatment protocols during and after inpatient TBI rehabilitation.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Abbreviations

ABS	Agitated Behavior Scale
ACA	Affordable Care Act
CMS	Centers for Medicare and Medicaid Services
CSI	Comprehensive Severity Index
FIM	Functional Independence Measure
PBE	Practice-based evidence
PTA	posttraumatic amnesia
RLOS	Rehabilitation length of stay
TBI	Traumatic Brain Injury
TBIMS	Traumatic Brain Injury Model Systems

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Table 1

Patient and Injury Characteristics for those with and without a Rehospitalization within 9 months Post Discharge

Characteristics	All Patients (N=1850)	Rehospitalization (N=510)	No Rehospitalization (N=1340)	P
Predictor available time of injury				
Age (mean, SD)	43.8 (20.9)	48.0 (21.5)	42.3 (20.4)	<0.001†
Days from injury to rehabilitation admission (mean, SD)	29.9 (35.6)	31.8 (35.8)	29.1 (35.6)	0.14
Employment prior to injury (%)				<0.001*
Employed and Student	4.1	3.1	4.4	
Employed only	47.0	41.2	49.3	
Unemployed	14.2	15.3	13.7	
Retired	22.3	30.2	19.3	
Student only	11.4	8.0	12.7	
Unknown	1.1	2.2	0.7	
Highest education achieved (%)				0.73
Some high school, no diploma	23.7	21.2	24.6	
High school diploma	26.2	27.6	25.6	
Work towards or Associate degree	17.7	18.4	17.4	
Work towards or Bachelors degree	20.0	20.0	19.9	
Work towards or Master/Doctoral degree	10.0	10.4	9.9	
Unknown	2.5	2.4	2.6	
Injury Cause (%)				<0.001*
Fall	31.0	38.0	28.3	
Motor vehicle crash	56.8	50.0	59.4	
Sports	1.9	0.8	2.3	
Violence	6.9	6.7	7.0	
Miscellaneous	3.4	4.5	3.0	
Male (%)	72.4	69.8	73.4	0.12*
Marital status at injury (%)				0.005*
Single/never married	43.1	37.1	45.4	
Married/common law	36.3	38.2	35.6	
Previously married	17.1	21.4	15.4	
Other/unknown	3.5	3.3	3.6	
Number of previous brain injuries (mean, SD)	0.1 (0.4)	0.2 (0.5)	0.1 (0.4)	0.035
Payer (%)				<0.001*
Medicare	18.9	27.6	15.6	
Medicaid	16.4	13.1	17.7	
Private insurance	24.7	22.7	25.4	
Centralized (single payer system)	6.3	2.7	7.7	

Characteristics	All Patients (N=1850)	Rehospitalization (N=510)	No Rehospitalization (N=1340)	P
Worker's compensation	5.9	5.9	5.9	
Self pay/None	4.8	4.5	4.9	
MCO/HMO	15.2	15.9	15.0	
No-fault auto insurance	4.6	4.1	4.8	
Other/unknown	3.2	3.3	3.1	
Race/Ethnicity (%)				0.08*
Black	14.6	15.1	14.4	
White non-Hispanic	76.1	78.4	75.2	
White Hispanic	5.6	4.1	6.2	
Other and unknown	3.7	2.4	4.2	
Predictor available at rehabilitation discharge				
Antipsychotic medication during the last 2 days of rehabilitation (%)	15.1	16.0	15.0	0.323*
Brain injury component of maximum CSI score (mean, SD)	49.1 (24.6)	52.0 (25.6)	48.0 (24.2)	0.002†
Non-brain injury component of maximum CSI score (mean, SD)	24.7 (20.7)	30.1 (23.7)	22.7 (19.1)	<0.001†
Discharge disposition (%)				<0.001*
Private home	85.2	78.4	87.8	
Acute care hospital	1.5	2.7	1.0	
Other post acute setting	13.3	18.8	11.2	
Discharge FIM motor score – raw (mean, SD)	63.1 (18.7)	57.5 (19.9)	65.2 (17.7)	<0.001†
Discharge FIM motor score – Rasch transformed (mean, SD)	54.5 (14.8)	51.3 (16.0)	57.5 (15.3)	<0.001†
Discharge FIM cognitive score – raw (mean, SD)	22.0 (6.6)	20.8 (7.0)	22.5 (6.3)	<0.001†
Discharge FIM cognitive score – Rasch transformed (mean, SD)	55.8 (15.7)	51.8 (16.5)	55.5 (14.0)	<0.001†
Discharge FIM cognitive score category (%)				<0.001*
Score <=15	15.8	21.4	13.7	
Score 16-20	22.4	26.9	20.7	
Score 21-25	28.8	22.9	31	
Score >=26	33.1	28.8	34.7	
Pneumonia before or during rehabilitation (%)	32.0	35.0	31.0	0.116*
Rehabilitation length of stay – excludes interruptions (mean, SD)	26.6 (19.7)	28.7 (20.5)	25.8 (19.3)	0.005†
Return to acute care during rehabilitation (%)	8.3	12.4	6.7	<0.001*
Seizures before or during rehabilitation (%)	14.8	19.0	13.0	0.001*
Urinary tract infection before or during rehabilitation (%)	30.7	38.0	28.0	<0.001*

NOTE: Abbreviations: MCO/HMO, Managed care organization/Health maintenance organization; CSI, Comprehensive Severity Index

*Chi-Square analysis.

† Two-sample t-test.

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Table 2

Primary causes for rehospitalization during 9 months after inpatient rehabilitation discharge

Rehospitalization reason	Rehospitalization frequency (n,%)	Number of individuals involved (n,%)	Rehospitalization frequency first month post discharge* (n,%)	Number of individuals involved* (n,%)
Infection	120 (15)	89 (14)	21 (18)	20 (18)
Neurologic	99 (13)	84 (13)	16 (14)	14 (13)
Neurosurgical	84 (11)	78 (12)	10 (9)	10 (9)
Injury/External cause	55 (7)	49 (8)	13 (11)	13 (12)
Psychiatric	53 (7)	43 (7)	6 (5)	5 (5)
Orthopedic	51 (7)	45 (7)	2 (2)	2 (2)
General	47 (6)	33 (5)	8 (7)	7 (7)
Cardiac	38 (5)	28 (4)	4 (3)	4 (4)
Gastrointestinal	36 (5)	31 (5)	6 (5)	5 (5)
Pulmonary	31 (4)	22 (3)	4 (3)	4 (4)
Vascular	20 (3)	19 (3)	6 (5)	6 (5)
Genitourinary/nephrology	15 (2)	9 (1)	3 (3)	2 (2)
Nutrition and hydration	12 (2)	12 (2)	3 (3)	3 (3)
Endocrine	12 (2)	7 (1)	1 (1)	1 (1)
Otolaryngological	10 (1)	10 (2)	0 (0)	0 (0)
Oncologic	9 (1)	6 (<1)	3 (3)	2 (2)
Gynecologic	4 (<1)	3 (<1)	1 (1)	1 (1)
Dermatologic (wound)	2 (<1)	1 (<1)	0 (0)	0 (0)
Lymphatic	1 (<1)	1 (<1)	1 (1)	1 (1)
Unknown	76 (10)	68 (11)	9 (8)	9 (8)
Total	**775**	**638**	**117***	**110***

*Approximate date is unknown for 115 (14.8%) rehospitalizations.

Table 3a

Prediction of patients having one or more rehospitalizations during 9 months after inpatient rehabilitation discharge

Outcome:	Any Rehospitalization		Rehospitalization for Infection		Rehospitalization for Injury	
Predictor	**Odds Ratio (95% Confidence Interval)**	**P**	**Odds Ratio (95% Confidence Interval)**	**P**	**Odds Ratio (95% Confidence Interval)**	**P**
Intercept		0.216		0.002		<.001
Predictor present at injury						
Age on admission	1.01 (1.00,1.01)	0.007			1.04 (1.03,1.06)	<.001
Cause of injury*: motor vehicle crash	0.73 (0.57,0.93)	0.010				
Cause of injury*: fall			2.24 (1.41,3.55)	<.001		
Number of previous brain injuries	1.29 (1.02,1.63)	0.032			2.03 (1.34,3.08)	<0.001
Predictor present at end of rehabilitation discharge						
Days from injury to rehabilitation admission					1.01 (1.00,1.02)	0.048
Seizures before or during rehabilitation	1.45 (1.09,1.93)	0.011				
Urinary tract infection before or during rehabilitation			1.87 (1.17,2.99)	0.009	2.42 (1.29,4.57)	0.006
Rehabilitation length of stay					0.95 (0.92,0.98)	0.001
FIM motor score - Rasch transformed	0.98 (0.97,0.99)	<.001	0.96 (0.94,0.97)	<.001		
Non-brain injury component of Maximum CSI score	1.01 (1.01,1.02)	<.001	1.01 (1.00,1.02)	0.017	1.03 (1.01,1.04)	<0.001
Number observations used	1850: Yes=510, No=1340		1429: Yes=89, No=1340		1389: Yes=49, No=1340	
c statistic	0.657		0.781		0.822	
Maximum rescaled R^2†	0.088		0.162		0.194	

NOTE: Abbreviations: Comprehensive Severity Index

*Reference categories for cause of injury are all of the categories combined that do not enter significantly into a model. The five categories are fall, motor vehicle crash, sports, violence, and miscellaneous.

†A scaled coefficient of determination (R^2).

Table 3b

Prediction of patients experiencing one or more rehospitalizations during 9-months after inpatient rehabilitation discharge

Outcome:	Rehospitalization for Psychiatric Cause		Rehospitalization for Seizure	
Predictor:	**Odds Ratio (95% Confidence Interval)**	**P**	**Odds Ratio (95% Confidence Interval**	**P**
Intercept		<.001		0.005
Predictor present at injury				
Male	0.50 (0.27,0.94)	0.031		
Cause of injury*: motor vehicle crash			0.33 (0.17,0.62)	<.001
Predictor present at end of rehabilitation discharge				
Pneumonia before or during rehabilitation			1.92 (1.05,3.52)	0.033
Seizures before or during rehabilitation	2.36 (1.15,4.82)	0.019	4.27 (2.36,7.75)	<.001
FIM cognitive score - Rasch transformed	0.98 (0.96,0.99)	0.043	0.96 (0.95,0.98)	<.001
Antipsychotic medication during the last 2 days of rehabilitation	3.03 (1.57,5.84)	0.001		
Number observations used	1383: Yes=43, No=1340		1391: Yes=51, No=1340	
c statistic	0.703		0.798	
Maximum rescaled R^2†	0.070		0.156	

NOTE:

*Reference categories for cause of injury are all of the categories combined that do not enter significantly into a model. The five categories are fall, motor vehicle crash, sports, violence, and miscellaneous.

†A scaled coefficient of determination (R^2).