Original Research

Successful Community Discharge Among Older Adults With Traumatic Brain Injury Admitted to Inpatient Rehabilitation Facilities

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Abstract *Objective:* To identify admission characteristics that predict a successful community discharge from an inpatient rehabilitation facility (IRF) among older adults with traumatic brain injury (TBI).

Design: In a retrospective cohort study, we leveraged probabilistically linked Medicare Administrative, IRF-Patient Assessment Instrument, and National Trauma Data Bank data to build a parsimonious logistic model to identify characteristics associated with successful discharge. Multiple imputation methods were used to estimate effects across linked datasets to account for potential data linkage errors.

Setting: Inpatient Rehabilitation Facilities in the U.S.

Participants: The sample included a mean of 1060 community-dwelling adults aged 66 years and older across 30 linked datasets (N=1060). All were hospitalized after TBI between 2011 and 2015 and then admitted to an IRF. The mean age of the sample was 79.7 years, and 44.3% of the sample was women.

Interventions: Not applicable.

Main Outcome Measure(s): Successful discharge home.

Results: Overall, 64.6% of the sample was successfully discharged home. A logistic model including 4 predictor variables: Functional Independence Measure motor (FIM-M) and cognitive (FIM-C) scores, pre-injury chronic conditions, and pre-injury living arrangement, that were significantly associated with successful discharge, resulted in acceptable discrimination (area under the curve: 0.76, 95% confidence interval [CI]: 0.72-0.81). Higher scores on the FIM-M (odds ratio [OR]:1.07, 95% CI: 1.05-1.09) and FIM-C (OR: 1.05, 95% CI: 1.02-1.08) were associated with greater odds of successful discharge, whereas living alone vs with others (OR: 0.46, 95% CI: 0.30-0.71) and a greater number of chronic conditions (OR: 0.94, 95% CI: 0.90-0.99) were associated with lower odds of successful discharge.

Conclusions: The results provide a parsimonious model for predicting successful discharge among older adults admitted to an IRF after a TBI-related hospitalization and provide clinically useful information to inform discharge planning.

Older adults represent most of individuals receiving care in inpatient rehabilitation facilities (IRF) after traumatic brain injury (TBI).[1] IRFs provide ongoing medical care and intensive rehabilitation to facilitate functional improvement and help patients return home.[2-10] At acute discharge, a patients' functional status, home environment, and perceived potential for improvement are critical to IRF referral decisions.[2,11-14] After IRF admission, clinicians help patients and their families plan for IRF discharge. The anticipated discharge disposition informs plans for home modifications, selection of caregivers, and referrals for future rehabilitative care, among other care decisions.[15-18] If patients can discharge home, the goal is for them to remain at home without needing to return to a hospital or long-term care facility, a goal reflected in the Centers for Medicare and Medicare Services "Discharge to Community" quality metric.[19]

Intensive and specialized rehabilitation is considered beneficial after brain injury.[20-22] However, age,[23-25] functional status,[23,24,26] comorbidity burden,[27,28] and injury severity[29] have the potential to affect patients' rehabilitation outcomes. Older adults with TBI in IRF differ from their younger counterparts in several of these areas, specifically, they are more likely to have mild brain injuries,[30] multiple chronic conditions,[31] and may have pre-injury declines in health that contributed to sustaining a TBI.[32] However, few studies examining predictors of IRF discharge disposition focused specifically on older adults with TBI. Frequently used data sources have traditionally underrepresented older adults,[33,34] only include individuals with moderate to severe injuries,[33-36] or lacked acute injury information (eg, acute severity) that may be relevant in traumatic injuries.[23,37] Some studies do not account for comorbidities or chronic conditions,[35,36,38] or are limited to those reported during the index admission.[26,39] As a result, there are gaps specific to older adults that may be relevant to IRF discharge planning.[31,32,38,40] Our objective is to help IRF clinicians by identifying a parsimonious combination of patient, injury, and health status characteristics known at IRF admission that predict a successful discharge home.

Methods

Data sources

This study used Medicare administrative data linked to the National Trauma Data Bank (NTDB). The NTDB does not contain individually identifiable information to allow a direct link to Medicare data. Therefore, the NTDB and Medicare data were probabilistically linked using a previously described Bayesian

multi-layer record linkage algorithm.[40-42] This record-linkage procedure simultaneously links trauma centers and patients within trauma centers. The Bayesian procedure assumes that all pairs of trauma centers from NTDB and Medicare follow a mixture model of links and non-links. In addition, within linked trauma centers, all pairs of individual records from the files follow a mixture model. Under the Bayesian paradigm, the unknown linkage is considered as missing data and sampled with model parameters simultaneously. Details of the linkage algorithm are described in detail in Shan et al (2022).[43] During the linking, we limited the acute hospitals and trauma centers to those with beds designated for burn care to limit the number of potential facilities and increase the accuracy of the linkage.

Medicare data sources included the Medicare Master Beneficiary Summary File (MBSF), Medicare Provider Analysis and Review File, hospice and home health claims, and the Chronic Conditions Warehouse segment of the MBSF. The Inpatient Rehabilitation Facility Patient Assessment Instrument (IRF-PAI) provided details of functional status (motor and cognitive), prior-living arrangements, and other patient demographic characteristics. Medicare Claims and post-acute assessment data were combined using previously described Residential History File methodology.[44] Residential History File was used to identify pre-injury health care utilization, and successful discharge, by identifying the initial discharge location and subsequent locations for 30 days. The NTDB provided details of the injury and acute management.[45] Brown University Institutional Review Board (IRB) approved the study. The IRB approved a waiver of HIPAA authorization under 45 CFR 164.512. The IRB also granted a waiver of informed consent under 45 CFR 46.116, so informed consent was not obtained.

Sample

In the NTDB and Medicare administrative linked data, we identified Medicare beneficiaries ages 66 years and older, hospitalized after a TBI, then admitted to an IRF between January 1, 2011, and September 30, 2015. The International Classification of Diseases, ninth revision was used to identify TBI cases (appendix 1). The sample was restricted to those enrolled in fee-for-service Medicare, living in the community pre-injury, with an IRF-PAI admission assessment.

Study outcome

The primary study outcome was successful community discharge, defined as a discharge from the IRF to the community with no admission to an inpatient health care facility or death for 30 days after discharge.[10] If individuals died during the IRF stay or the subsequent 30 days, were discharged to the hospital or a Skilled Nursing Facility (SNF), or were discharged home and then were admitted to a health care facility, they were not considered successfully dischargedsuccessfully discharged.

Predictor variables

Candidate variables included sociodemographic, pre-injury, and injury characteristics hypothesized to affect successful discharge. Sociodemographic characteristics included age, sex (male and female), race (black, white, other/unknown), and dual Medicaid/Medicare enrollment from the MBSF. Marital status (currently married, not currently married) and pre-injury living arrangements (living alone, not living alone) were obtained from the IRF-PAI. A count of pre-injury chronic conditions (with all cancer diagnoses collapsed into a single diagnosis; range 0-20) were obtained from the Chronic Conditions Warehouse. Functional Independence Measure (FIM) from the IRF-PAI reflected motor and cognitive status. The FIM includes ratings of 13 motor items (eg, eating, grooming, bathing, dressing (upper and lower body), toileting, bladder and bowel management, transfers, locomotion, stairs) and 5 cognitive items (comprehension, expression, social interaction, problem-solving, memory) rated on a 1 (dependent) to 7 (independent) scale. Injury characteristics obtained from the NTDB included the mechanism of injury (fall, motor vehicle, other/unknown), Glasgow Coma Scale (GCS) scores from the emergency department and categorized into mild (13-15), moderate (9-12), and severe (3-8), and worst head injury using the Abbreviated Injury Scale's (AIS) 1 (minor) to 6 (maximal) point scale.[45] For the GCS and AIS scores, not applicable and not recorded responses were collapsed into an "other" category. Additionally, we included variables reflecting non head injuries ($\geq$AIS 2) and an intensive care unit admission.

Analyses

The linked NTDB and Medicare data were used for all analyses. We used a multiple imputation approach to account for potential errors in the linkage process. Using this approach, we created 30 datasets from the posterior distribution of the linkage algorithm, each of which contained linked records that represent the same patient.[46,47] These linkage structures are sampled from the Bayesian linkage model based on 1000 Markov chain Monte-Carlo iterations with 250 burn-in iterations. To ensure that the linkage structures are independent, we used every 25th iteration to impute the missing linkage structure. Each dataset was analyzed separately, and then multiple imputation combining rules were used to obtain point and interval estimates.[48] Specifically, for the statistic of interest θ, let $\hat{\theta}^{(m)}$ be its estimate at linked data m be and $U^{(m)}$ its corresponding standard error. The point estimates for θ is $\hat{\theta} = \frac{1}{m}\sum_m \hat{\theta}^{(m)}$, and the corresponding sampling variance is $T = \overline{U} + (1 + \frac{1}{m})B$, where $\overline{U} = \frac{1}{m}\sum_m U^{(m)}$ and $B = \frac{1}{m-1}\sum_m \left(\hat{\theta}^{(m)} - \hat{\theta}\right)^2$. These combining rules were used to generate interval estimates for the area under the curve (AUC) and model parameters.[49] All analyses were completed with Stata 16.0 Software. Additional details and code describing the analyses can be found at Brown Digital Repository: https://doi.org/10.26300/q8bq-qb54.

We describe the sample using estimated means and proportions. We use bivariate logistic regression to examine the unadjusted association between each potential predictor and the odds of successful discharge. We then use a 2-level hierarchical logistic regression model to evaluate the relation between the predictors and successful discharge. We adjusted for sociodemographic, pre-injury, and injury

characteristics at the first level and IRF facility at the second level to account for additional variability in IRF facilities that could affect successful discharge. To identify a parsimonious model, we relied on a backward elimination algorithm with Rubin's Rule Wald statistics.[49] This method was shown to preserve the type 1 error rate.[50] In short, this method begins by estimating in each imputed dataset the full model that includes all first-level candidate predictor variables. Pooled Wald statistics across imputed datasets are calculated using Rubin's Rule for all of the coefficients in the model.[50] The coefficient with the largest *P* value using the pooled Wald statistic is removed from the model, and the procedure is repeated with the reduced model. The procedure concludes when all of the coefficients in the model are significantly different from zero at the 0.05 level.[50]

We report the odds ratio for each variable in the final model, and use the *mimrgns* Stata module to calculate the predicted probability of successful discharge.[51] We calculate the AUC as described above to compare the discriminatory ability of the full and final model.

Results

The sample included a mean of 1060 (standard deviation 332) older adults with TBI across the 30 datasets, 64.6% (95% confidence interval [CI]: 61.0-68.3) of whom successfully discharged home. The mean age was 79.7 years, and most were men (55.7%), white (91.0%), and had mild injuries (82.3%). Additional details are provided in table 1. In the bivariate analyses, living alone pre-injury (odds ratio [OR]: 0.58, 95% CI: 0.41, 0.81), history of Alzheimer's disease or dementia (OR: 0.64, 95% CI: 0.42, 0.98), prior inpatient post-acute care use (OR: 0.55, 95% CI: 0.32, 0.95), and number of pre-injury chronic conditions (OR: 0.95, 95% CI: 0.91, 0.99) were associated with a lower likelihood of successful discharge. Being married (OR: 1.44, 95% CI: 1.01, 2.07) and higher admission Functional Independence Measure-Motor (FIM-M; OR: 1.08, 95% CI: 1.06, 1.09) and Functional Independence Measure-Cognitive (FIM-C) scores (OR: 1.10, 95% CI: 1.07, 1.13) were associated with higher odds of successful discharge. Complete results are provided in table 2.

The final model included 4 variables, living alone before injury, number of chronic conditions, and admission FIM-M and FIM-C scores (table 3). Living alone compared with not living alone (OR: 0.44, 95% CI: 0.28-0.68) and a higher number of chronic conditions (OR: 0.94, 95% CI: 0.90-0.99) were significantly associated with lower odds of successful discharge, whereas higher (better) scores on the FIM-M (OR: 1.07, 95% CI: 1.05-1.09) and FIM-C (OR: 1.05, 95% CI: 1.01, 1.08) were associated with higher odds of successful discharge. The ability to discriminate successful discharge was similar for the full model (AUC: 0.78 [95% CI: 0.74-0.82]) and the final four-predictor model (AUC: 0.76 [95% CI: 0.72-0.81]).

Figure 1 reflects the predicted probability of successful discharge from the final model, based on FIM-M score and pre-injury living arrangements (living alone or not living alone) with FIM-C and chronic conditions held at the mean. As observed in figure 1, individuals with higher FIM-M scores have a higher probability of successful discharge, as do those who lived with others before injury. For example, individuals

Table 1 Patient and injury characteristics	
Characteristics	Full Sample Estimate (95% CI)
n, mean	1060 (332)
Age, y, mean	79.7 (78.9, 80.6)
Women, %	44.3 (40.2, 48.6)
Race, %	
White	91.0 (88.4, 93.5)
Black	3.8 (2.3, 5.3)
Other	5.2 (3.3, 7.2)
Currently married, %	55.2 (51.3, 59.1)
Lived alone, %	30.0 (26.4, 33.6)
Medicare and Medicaid Enrolled, %	10.0 (7.9, 12.3)
Number of pre-injury chronic conditions, mean	8.8 (8.4, 9.2)
Pre-injury Alzheimer disease or dementia, %	20.5 (17.5, 23.4)
Prior inpatient PAC use	9.2 (7.2, 11.2)
Mechanism, %	
Fall	75.7 (71.6, 79.8)
Motor vehicle	17.1 (13.6, 20.6)
Other/unknown	7.2 (5.1, 9.2)
GCS,* %	
Mild (13-15)	82.3 (78.6, 86.2)
Moderate (9-12)	4.4 (2.8, 6.0)
Severe (3-8)	6.5 (4.4, 8.6)
AIS-Head-Max,* %	
1	7.0 (4.6, 9.3)
2	11.4 (7.4, 15.5)
3	17.5 (13.5, 21.4)
4	48.5 (44.0, 53.0)
5	14.1 (10.1, 18.2)
Intensive care admission, %	80.2 (76.9, 83.6)
Non-head injury, %	50.0 (45.5, 54.5)
FIM-Motor, mean	33.3 (32.3, 34.4)
FIM-Cognitive, mean	18.4 (17.8, 18.9)

Abbreviations: AIS, abbreviated injury scale score; FIM, functional independence measure; GCS, glasgow coma scale score.
  * Excluding "not applicable/not documented" category.

who lived with others with FIM-M scores of 26 (maximum assistance across all items), 39 (moderate assistance across all items), and 52 (minimum assistive across all items) would have 62%, 80%, and 90% probabilities of successful discharge, respectively. Individuals with the same FIM-M scores[26,39,52] who lived alone would have 43%, 64%, and 80% probabilities of successful discharge home, respectively. However, the benefit of living with others diminishes as the admission FIM-M score increases.

Figure 2 reflects the predicted probability of successful discharge based on the FIM-C score and pre-injury living arrangements with FIM-M and chronic conditions held the mean. As reflected in figure 2, a higher FIM-C score and living with others vs living alone is associated with a higher probability of successful discharge. For individuals who lived alone, a FIM-C score of 10 (maximum assist across all items) was associated with a 46% probability of successful discharge, whereas a score of 20 (minimum assist across all items) was associated with a 56% probability of successful

Table 2 Bivariate associations between patient characteristics and successful discharge

Characteristics	Not Successful Discharge	Successful Discharge	Est. Odds Ratio (95% CI)	P Value
Age, y, mean	80.4 (79.4, 81.5)	79.3 (78.3, 80.3)	0.98 (0.96, 1.00)	0.06
Women, %	42.0 (35.4, 48.5)	45.7 (40.3, 51.1)	1.17 (0.82, 1.65)	0.38
Race, %				
White	92.1 (88.6, 95.7)	90.3 (87.2, 93.5)	Ref.	0.72
Black	3.4 (1.0, 5.8)	4.0 (2.0, 5.9)	1.19 (0.48, 2.93)	
Other	4.4 (1.7, 7.2)	5.7 (3.3, 8.1)	1.32 (0.63, 2.82)	
Currently married, %	**49.6 (42.5, 56.7)**	**58.3 (53.4, 63.2)**	**1.44 (1.01, 2.07)**	**0.05**
Lived alone, %	**37.6 (31.6, 43.7)**	**25.9 (21.6, 30.1)**	**0.58 (0.41, 0.81)**	**<0.01**
Medicare and Medicaid eligible, %	13.2 (9.0, 17.4)	8.4 (5.7, 11.1)	0.60 (0.38, 1.10)	0.06
Number of pre-injury chronic conditions, mean	**9.3 (8.9, 9.8)**	**8.5 (8.0, 9.1)**	**0.95 (0.91, 0.99)**	**0.02**
Pre-injury Alzheimer's disease or dementia, %	**25.4 (19.7, 31.0)**	**17.8 (14.1, 21.5)**	**0.64 (0.42, 0.98)**	**0.04**
Prior PAC use, %	**12.6 (8.4, 16.8)**	**7.4 (5.0, 9.7)**	**0.55 (0.32, 0.95)**	**0.03**
Mechanism, %				
Fall	75.7 (69.6, 81.9)	75.7 (70.8, 80.7)	Ref.	0.98
Motor vehicle	16.9 (11.7, 22.0)	17.3 (13.1, 21.4)	1.02 (0.66, 1.58)	
Other/unknown	7.4 (3.9, 10.8)	7.0 (4.3, 9.7)	0.95 (0.48, 1.87)	
GCS,* %				0.80
Mild (13-15)	81.6 (76.3, 86.9)	82.8 (78.2, 87.4)	Ref	
Moderate (9-12)	3.7 (1.3, 6.2)	4.8 (2.7, 6.9)	1.28 (0.57, 2.91)	
Severe (3-8)	5.9 (2.6, 9.2)	6.8 (4.2, 9.5)	1.15 (0.55, 2.44)	
AIS-Head-Max,* %				0.97
1	6.8 (3.3, 10.3)	7.0 (3.9, 10.2)	Ref.	
2	11.3 (5.6, 17.1)	11.5 (7.3, 15.6)	0.99 (0.41, 2.36)	
3	16.8 (11.5, 22.1)	17.9 (12.9, 23.1)	1.03 (0.47, 2.50)	
4	48.9 (41.8, 55.8)	48.3 (42.9, 53.7)	0.95 (0.46, 1.97)	
5	13.6 (8.3, 19.0)	14.4 (9.9, 18.9)	1.02 (0.45, 2.30)	
Intensive care admission, %	79.9 (74.5, 85.3)	80.4 (76.2, 84.6)	1.03 (0.67, 1.57)	0.90
Non-head injury, %	48.4 (40.8, 55.9)	50.9 (45.2, 56.6)	1.11 (0.76, 1.62)	0.60
FIM-Motor, mean	**26.6 (25.2, 28.1)**	**37.0 (35.7, 38.3)**	**1.08 (1.06, 1.09)**	**<0.01**
FIM-Cognitive, mean	**15.3 (14.2, 16.4)**	**20.0 (19.3, 20.8)**	**1.10 (1.07, 1.13)**	**<0.01**

Abbreviations: AIS, abbreviated injury scale score; FIM, functional independence measure; GCS, glasgow coma scale score.
  * Results exclude the "not applicable/not documented" category. **Bold** indicates a significant difference at P<.05.

Table 3 Results from the final multivariable model predicting successful discharge

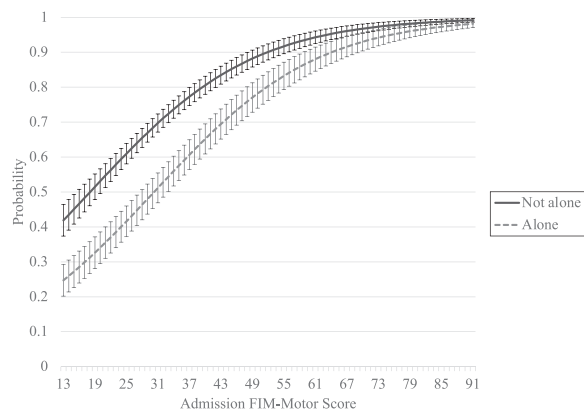|	Est. Odds Ratio (95% CI)
Lived alone	0.44 (0.28, 0.68)
Number of chronic conditions	0.94 (0.90, 0.99)
FIM-Motor score	1.07 (1.05, 1.09)
FIM-Cognitive score	1.05 (1.01, 1.08)

NOTE. Final model AUC=0.76 (95% CI: 0.72, 0.81).
Abbreviation: FIM, functional independence measure.

Fig 1 Probability of a successful discharge by admission FIM-motor scores, stratified by pre-admission living arrangement.

discharge. Among those living with others, the same scores were associated with a 63% and 72% probability of successful discharge, respectively.

Discussion

In a sample of older adults with TBI admitted to IRF for post-acute care, 64.7% successfully discharge home at the end of the IRF stay. A model including 4 predictor variables: FIM-M score, FIM-C score, number of chronic conditions, and living arrangements (living alone vs not alone) had acceptable discrimination of successful discharge that was similar to a larger model that included many clinical and demographic
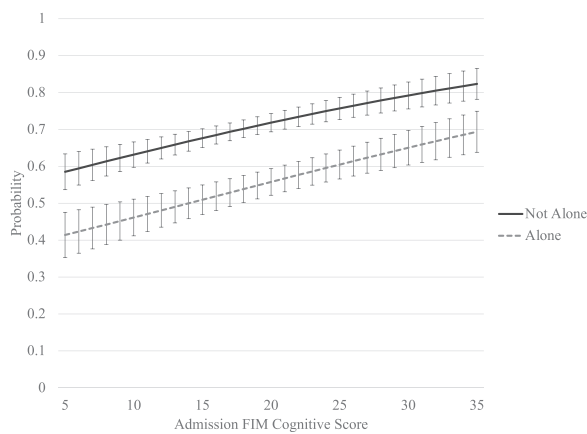
Fig 2 Probability of a successful discharge by admission FIM-cognitive scores, stratified by pre-admission living arrangement.

characteristics.[52] Notably, markers of acute injury severity at admission (AIS scores, GCS, scores, intensive care unit use) did *not* display an association with successful discharge. While it is clinically reasonable to expect fewer chronic conditions and higher admission motor and cognitive function would be associated with returning home, it is informative that these characteristics, combined with living arrangement, provided acceptable discrimination of successful discharge.

In interpreting these results, we consider pre-injury living arrangement to be a proxy for post-discharge at home support, as most individuals returning home, would likely return to their pre-injury environment. Given this interpretation, the association between living arrangement and the ability to successfully return home highlights the critical importance of family and social support in discharge planning. Our findings demonstrate the extent to which family and caregivers are relied upon to provide ongoing care to individuals with TBI who would not otherwise be able to return home. Of course, in individual cases, close involvement with potential caregivers is critical in understanding their availability and capabilities for providing the required care.[53,54]

Our findings align with our previous work, which identified a significant association between functional and cognitive status and successful discharge among older adults with TBI in SNF settings.[42] The significant role of functional status and caregiver support or marital status has similarly been observed in individuals with stroke,[11,55] and adults with TBI across age groups.[23,24] The relation between the number of chronic conditions is consistent with literature identifying the high prevalence and negative effect of chronic conditions on acute and post-acute outcomes in individuals with TBI.[56−58] Finally, our findings support literature that suggests positive outcomes for most of older adults who receive care in IRFs, despite anecdotal concern older adults' tolerance of rehabilitation-intensive IRF settings.[4,26,36,59] However, individuals with post-acute care needs may alternatively be admitted to SNFs, or long-term acute care hospitals.[9,21,60] Post-acute care episodes may include 1 or multiple of these settings.[21,26,59] Despite differences between these levels of care, there is significant overlap in the patient populations served without clear guidance to inform selection of the most appropriate post-acute setting for a particular

patient.[9,21,26,59-61] In light of efforts to control Medicare post-acute care spending,[62,63] additional work is needed to explore the effectiveness of the varied post-acute care options for older adults with TBI.

Study limitations

Our study has several limitations. First, to analyze the linked data, we assume that the linkage is non-informative, meaning that variables that are unique to each data file do not contribute to the linkage. Whereas this assumption is commonly made when using linked files,[64] use of weakly informative variables for the linkage may result in violation of this assumption. Higher quality links increase the likelihood of meeting the non-informative linkage assumption. Thus, our linkage process included many patient-level and hospital-level variables to increase the quality of the links. Additionally, we used multiple imputation methods to account for potential errors in the linkage.

Second, in the included study years (2011-2015), the FIM measure was collected as part of the IRF-PAI assessment. However, as of October 2019, the FIM was replaced with the cross-setting "Section GG."[65] As a result, the specific FIM scores associated with the probability of successful discharge may have less utility. However, we believe that the relations observed between the motor and cognitive abilities and successful discharge, previously measured by the FIM and now reflected in "Section GG," remain clinically informative.

Third, our model only included characteristics available in our data sources. For example, we did not have information on pre-injury functional status that may be related to both sustaining a TBI and admission function.[32,66] Additional research into other characteristics could improve our model and the ability to predict successful discharge among this population. We also used a backward elimination procedure to identify a parsimonious model which may result in overfitting.[67] However, previous variable selection studies with multiple imputation have shown that this method preserved the type 1 error[50] and produced a prognostic model with good performance in an independent validation sample.[49] Moreover, our final model is relatively small and includes only 4 variables.

It should be noted that we selected the term "successful discharge" to align with terminology used by Centers for Medicare and Medicare Services and other investigations of post-acute care outcomes.[10,19,68-70] However, achieving a successful discharge directly from an IRF is not the only pathway for an older adult with TBI to have a successful outcome. Given the multiple options for post-acute care individuals who do not discharge directly from IRF may do so after additional care in a subsequent setting.

Finally, our sample was limited to older adults hospitalized with TBI, enrolled in fee-for-service Medicare, who received acute care in an NTDB-participating Trauma Center (considered representative of Level I and II trauma centers) with dedicated burn beds. Burn beds are often in larger trauma facilities and certified burn centers that have resources and infrastructure to support resource intensive care.[69,71] Thus, our results may not be generalizable to individuals who are enrolled in Medicare

Advantage, received acute care at a Level III or IV trauma center, or a facility without burn beds, or received other types of post-acute care. Additionally, the sample was predominantly comprised white beneficiaries. Although this is consistent with other samples of older adults with TBI in IRFs,[26,30,34,72] the low proportion of non-white individuals limited our ability to examine differences in discharge disposition across more specific racial and ethnic groups.

Conclusions

Among the growing population of older adults with TBI in IRFs, most successfully return home after IRF discharge. We examined a variety of demographic, health, and injury characteristics and found that admission motor and cognitive abilities, chronic conditions, and living arrangement significantly predict successful discharge home. Knowledge of the relation between these 4 variables and the successful discharge outcome may be helpful to clinicians working with patients and families to develop discharge plans. The significant role of living arrangement, interpreted as a proxy for social support, speaks to the importance that family and caregivers play in helping patients return home and remain home. Our results, along with evidence suggesting high levels of stress, burden, and unmet needs among informal caregivers of individuals with TBI, highlight the importance of caregiver training and continued research into effective strategies for supporting caregivers during the transition home and after.[73-81]

Suppliers

StataCorp. 2019. Stata Statistical Software: Release 16. College Station, TX: StataCorp LLC.

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References

1. Lamm AG, Goldstein R, Giacino JT, Niewczyk P, Schneider JC, Zafonte R. Changes in patient demographics and outcomes in the Inpatient Rehabilitation Facility Traumatic Brain Injury Population from 2002 to 2016: implications for patient care and clinical trials. J Neurotrauma 2019;36:2513-20.
2. Jette DU, Grover L, Keck CP. A qualitative study of clinical decision making in recommending discharge placement from the acute care setting. Phys Ther 2003;83:224-36.
3. Malec JF, Mandrekar JN, Brown AW, Moessner AM. Injury severity and disability in the selection of next level of care following acute medical treatment for traumatic brain injury. Brain Injury 2009;23:22-9.
4. Zarshenas S, Colantonio A, Alavinia SM, Jaglal S, Tam L, Cullen N. Predictors of discharge destination from acute care in patients with traumatic brain injury: a systematic review. J Head Trauma Rehabil 2019;34:52-64.
5. Luppa M, Luck T, Weyerer S, Konig HH, Brahler E, Riedel-Heller SG. Prediction of institutionalization in the elderly. A systematic review. Age Ageing 2010;39:31-8.
6. Eum RS, Brown AW, Watanabe TK, et al. Risk factors for institutionalization after traumatic brain injury inpatient rehabilitation. J Head Trauma Rehabil 2017;32:158-67.
7. Portelli R, Lowe D, Irwin P, Pearson M, Rudd AG. Intercollegiate Stroke Working P. Institutionalization after stroke. Clin Rehabil 2005;19:97-108.
8. Kane RL. Assessing the effectiveness of postacute care rehabilitation. Arch Phys Med Rehabil 2007;88:1500-4.
9. Buntin MB. Access to postacute rehabilitation. Arch Phys Med Rehabil 2007;88:1488-93.
10. Leland NE, Gozalo P, Christian TJ, et al. An examination of the first 30 days after patients are discharged to the community from hip fracture postacute care. Med Care 2015;53:879-87.
11. Tanwir S, Montgomery K, Chari V, Nesathurai S. Stroke rehabilitation: availability of a family member as caregiver and discharge destination. Eur J Phys Rehabil Med 2014;50:355-62.
12. Longley V, Peters S, Swarbrick C, Bowen A. What factors affect clinical decision-making about access to stroke rehabilitation? A systematic review. Clin Rehabil 2019;33:304-16.
13. Lam Wai Shun P, Swaine B, Bottari C. Combining scoping review and concept analysis methodologies to clarify the meaning of rehabilitation potential after acquired brain injury. Disabil Rehabil 2022;44:817-25.
14. Jette DU, Stilphen M, Ranganathan VK, Passek SD, Frost FS, Jette AM. AM-PAC "6-Clicks" functional assessment scores predict acute care hospital discharge destination. Phys Ther 2014;94:1252-61.
15. Greysen SR, Hoi-Cheung D, Garcia V, et al. Missing pieces—functional, social, and environmental barriers to recovery for vulnerable older adults transitioning from hospital to home. J Am Geriatr Soc 2014;62:1556-61.
16. Yam CH, Wong EL, Cheung AW, Chan FW, Wong FY, Yeoh EK. Framework and components for effective discharge planning system: a Delphi methodology. BMC Health Serv Res 2012;12:396.
17. Falvey JR, Burke RE, Malone D, Ridgeway KJ, McManus BM, Stevens-Lapsley JE. Role of physical therapists in reducing hospital readmissions: optimizing outcomes for older adults during care transitions from hospital to community. Phys Ther 2016;96:1125-34.
18. Piccenna L, Lannin NA, Gruen R, Pattuwage L, Bragge P. The experience of discharge for patients with an acquired brain injury from the inpatient to the community setting: a qualitative review. Brain Inj 2016;30:241-51.
19. 81 Federal Register: Medicare Program; Prospective Payment System and Consolidated Billing for Skilled Nursing Facilities for FY 2017, SNF Value-Based Purchasing Program, SNF Quality Reporting Program, and SNF Payment Models Research; Final Rule (42 CFR Part 413) (2016).
20. Horn SD, Corrigan JD, Beaulieu CL, et al. Traumatic brain injury patient, injury, therapy, and ancillary treatments associated with outcomes at discharge and 9 months postdischarge. Arch Phys Med Rehabil 2015;96(8 Suppl):S304-29.
21. Mellick D, Gerhart KA, Whiteneck GG. Understanding outcomes based on the post-acute hospitalization pathways followed by persons with traumatic brain injury. Brain Inj 2003;17:55-71.
22. Hong I, Goodwin JS, Reistetter TA, et al. Comparison of functional status improvements among patients with stroke receiving postacute care in inpatient rehabilitation vs skilled nursing facilities. JAMA Netw Open 2019;2:e1916646.
23. Eum RS, Seel RT, Goldstein R, et al. Predicting institutionalization after traumatic brain injury inpatient rehabilitation. J Neurotrauma 2015;32:280-6.

24. Corrigan JD, Horn SD, Barrett RS, et al. Effects of patient preinjury and injury characteristics on acute rehabilitation outcomes for traumatic brain injury. Arch Phys Med Rehabil 2015;96(8 Suppl):S209-21. e6.

25. LeBlanc J, de Guise E, Gosselin N, Feyz M. Comparison of functional outcome following acute care in young, middle-aged and elderly patients with traumatic brain injury. Brain Inj 2006;20:779-90.

26. Chang PF, Ostir GV, Kuo YF, Granger CV, Ottenbacher KJ. Ethnic differences in discharge destination among older patients with traumatic brain injury. Arch Phys Med Rehabil 2008;89:231-6.

27. Kumar RG, Olsen J, Juengst SB, et al. Comorbid conditions among adults 50 years and older with traumatic brain injury: examining associations with demographics, healthcare utilization, institutionalization, and 1-year outcomes. J Head Trauma Rehabil 2019;34:224-32.

28. Howrey BT, Graham JE, Pappadis MR, Granger CV, Ottenbacher KJ. Trajectories of functional change after inpatient rehabilitation for traumatic brain injury. Arch Phys Med Rehabil 2017;98:1606-13.

29. Corrigan JD, Zheng T, Pinto SM, et al. Effect of preexisting and co-occurring comorbid conditions on recovery in the 5 years after rehabilitation for traumatic brain injury. J Head Trauma Rehabil 2020;35:E288-98.

30. Cuthbert JP, Harrison-Felix C, Corrigan JD, et al. Epidemiology of adults receiving acute inpatient rehabilitation for a primary diagnosis of traumatic brain injury in the United States. J Head Trauma Rehabil 2015;30:122-35.

31. Kumar RG, Juengst SB, Wang Z, et al. Epidemiology of comorbid conditions among adults 50 years and older with traumatic brain injury. J Head Trauma Rehabil 2018;33:15-24.

32. Dams-O'Connor K, Gibbons LE, Landau A, Larson EB, Crane PK. Health problems precede traumatic brain injury in older adults. J Am Geriatr Soc 2016;64:844-8.

33. Corrigan JD, Cuthbert JP, Whiteneck GG, et al. Representativeness of the traumatic brain injury model systems National Database. J Head Trauma Rehabil 2012;27:391–403.

34. Cuthbert JP, Corrigan JD, Whiteneck GG, et al. Extension of the representativeness of the Traumatic Brain Injury Model Systems National Database: 2001 to 2010. J Head Trauma Rehabil 2012;27:E15-27.

35. Cifu DX, Kreutzer JS, Marwitz JH, Rosenthal M, Englander J, High W. Functional outcomes of older adults with traumatic brain injury: a prospective, multicenter analysis. Arch Phys Med Rehabil 1996;77:883-8.

36. Frankel JE, Marwitz JH, Cifu DX, Kreutzer JS, Englander J, Rosenthal M. A follow-up study of older adults with traumatic brain injury: taking into account decreasing length of stay. Arch Phys Med Rehabil 2006;87:57-62.

37. Reistetter TA, Graham JE, Deutsch A, Granger CV, Markello S, Ottenbacher KJ. Utility of functional status for classifying community versus institutional discharges after inpatient rehabilitation for stroke. Arch Phys Med Rehabil 2010;91:345-50.

38. Mosenthal AC, Livingston DH, Lavery RF, et al. The effect of age on functional outcome in mild traumatic brain injury: 6-month report of a prospective multicenter trial. J Trauma 2004;56:1042-8.

39. Thompson HJ, McCormick WC, Kagan SH. Traumatic brain injury in older adults: epidemiology, outcomes, and future implications. J Am Geriatr Soc 2006;54:1590-5.

40. Shan M, Thomas KS, Gutman R. A Bayesian multiLayer record linkage procedure to analyze postacute care recovery of patients with traumatic brain injury. Biostatistics 2022. kxac016.

41. Evans E, Krebill C, Gutman R, et al. Functional motor improvement during inpatient rehabilitation among older adults with traumatic brain injury. PM R 2021;14:417-27.

42. Evans E, Gutman R, Resnik L, et al. Successful community discharge among older adults with traumatic brain injury in skilled nursing facilities. J Head Trauma Rehabil 2021;36:E186-98.

43. Shan M, Thomas KS, Gutman R. A multiple imputation procedure for record linkage and causal inference to estimate the effects of home-delivered meals. Ann Appl Statist 2021;15:412-36.

44. Intrator O, Hiris J, Berg K, Miller SC, Mor V. The residential history file: studying nursing home residents' long-term care histories(*). Health Serv Res 2011;46(1 Pt 1):120-37.

45. Hashmi ZG, Kaji AH, Nathens AB. Practical guide to surgical data sets: National Trauma Data Bank (NTDB). JAMA Surg 2018;153:852-3.

46. Gutman R, Sammartino CJ, Green TC, Montague BT. Error adjustments for file linking methods using encrypted unique client identifier (eUCI) with application to recently released prisoners who are HIV+. Stat Med 2016;35:115-29.

47. Gutman R, Afendulis CC, Zaslavsky AM. A Bayesian procedure for file linking to analyze end-of-life medical costs. J Am Stat Assoc 2013;108:34-47.

48. Rubin DB. Multiple imputation for nonresponse in surveys. New York: Wiley classics library. Wiley-Interscience; 2004. p. 287. Vol. 81xxix.

49. Austin PC, Lee DS, Ko DT, White IR. Effect of variable selection strategy on the performance of prognostic models when using multiple imputation. Circ Cardiovasc Qual Outcomes 2019;12:e005927.

50. Wood AM, White IR, Royston P. How should variable selection be performed with multiply imputed data? Stat Med 2008;27:3227-46.

51. MIMRGNS: Stata Module to run margins after mi estimate. Statistical Software Components S457795, Boston College Department of Economics; 2014 Version January 12, 2020.

52. Mandrekar JN. Receiver operating characteristic curve in diagnostic test assessment. J Thorac Oncol 2010;5:1315-6.

53. Young ME, Lutz BJ, Creasy KR, Cox KJ, Martz C. A comprehensive assessment of family caregivers of stroke survivors during inpatient rehabilitation. Disabil Rehabil 2014;36:1892-902.

54. Burgdorf JG, Fabius CD, Riffin C, Wolff JL. Receipt of posthospitalization care training among Medicare beneficiaries' family caregivers. JAMA Netw Open 2021;4:e211806.

55. Nguyen VQ, PrvuBettger J, Guerrier T, et al. Factors associated with discharge to home versus discharge to institutional care after inpatient stroke rehabilitation. Arch Phys Med Rehabil 2015;96:1297-303.

56. Hirshson CI, Gordon WA, Singh A, et al. Mortality of elderly individuals with TBI in the first 5 years following injury. NeuroRehabilitation 2013;32:225-32.

57. Thompson HJ, Dikmen S, Temkin N. Prevalence of comorbidity and its association with traumatic brain injury and outcomes in older adults. Res Gerontol Nurs 2012;5:17-24.

58. Lecours A, Sirois MJ, Ouellet MC, Boivin K, Simard JF. Long-term functional outcome of older adults after a traumatic brain injury. J Head Trauma Rehabil 2012;27:379-90.

59. Graham JE, Radice-Neumann DM, Reistetter TA, Hammond FM, Dijkers M, Granger CV. Influence of sex and age on inpatient rehabilitation outcomes among older adults with traumatic brain injury. Arch Phys Med Rehabil 2010;91:43-50.

60. Gage B, Morley M, Smith L, et al. Post-acute care payment reform demonstration, Vol. 1. 2012. Available at: https://www.cms.gov/Research-Statistics-Data-and-Systems/Statistics-Trends-and-Reports/Reports/Downloads/PAC-PRD_FinalRpt_Vol1of4.pdf. Accessed August 1, 2021.

61. Lam Wai Shun P, Bottari C, Dube S, Grondin M, Swaine B. Factors influencing clinicians' referral or admission decisions for post-acute stroke or traumatic brain injury rehabilitation: a scoping review. PM R 2021 Aug 13. [Epub ahead of print].

62. Report to the Congress: Medicare and the Healthcare Delivery System. 2016. Available at: http://www.medpac.gov/docs/default-source/reports/june-2016-report-to-the-congress-medicare-and-the-health-care-delivery-system.pdf?sfvrsn=0. Accessed August 1, 2021.

63. Report to the Congress: Medicare Payment Policy (2019). Available at: https://www.medpac.gov/document/march-2019-report-to-the-congress-medicare-payment-policy/. Accessed July 1, 2022.

64. Chambers R, Chipperfield J, Davis W, Kovacevic M. Inference based on estimating equations and probability-linked data. Centre for Statistical and Survey Methodology, University of Wollongong; 2009 Working Paper.

65. Centers for Medicare & Medicaid Services (CMS) HHS. Medicare Program; Prospective Payment System and Consolidated Billing for Skilled Nursing Facilities (SNF) Final Rule for FY 2019, SNF Value-Based Purchasing Program, and SNF Quality Reporting Program. Final rule. Fed Regist 2018;83:39162-290.

66. Lew HL, Lee E, Date ES, Zeiner H. Influence of medical comorbidities and complications on FIM change and length of stay during inpatient rehabilitation. Am J Phys Med Rehabil 2002;81:830-7.

67. Zhao Y, Long Q. Variable selection in the presence of missing data: imputation-based methods. Wiley Interdiscip Rev Comput Stat 2017;9:e1402.

68. Leland NE, Roberts P, De Souza R, Hwa Chang S, Shah K, Robinson M. Care Transition processes to achieve a successful community discharge after postacute care: a scoping review. Am J Occup Ther 2019;73. 7301205140p1-7301205140p9.

69. Gozalo P, Leland NE, Christian TJ, Mor V, Teno JM. Volume matters: returning home after hip fracture. J Am Geriatr Soc 2015;63:2043-51.

70. Ryskina KL, Yuan Y, Werner RM. Postacute care outcomes and medicare payments for patients treated by physicians and advanced practitioners who specialize in nursing home practice. Health Serv Res 2019;54:564-74.

71. Klein MB, Nathens AB, Heimbach DM, Gibran NS. An outcome analysis of patients transferred to a regional burn center: transfer status does not impact survival. Burns 2006;32:940-5.

72. Cuthbert JP, Whiteneck GG, Corrigan JD, Bogner J. The reliability of a computer-assisted telephone interview version of the Ohio State University Traumatic Brain Injury Identification Method. J Head Trauma Rehabil 2016;31:E36-42.

73. Fann JR, Hart T, Ciol MA, et al. Improving transition from inpatient rehabilitation following traumatic brain injury: protocol for the BRITE pragmatic comparative effectiveness trial. Contemp Clin Trials 2021;104:106332.

74. Kratz AL, Sander AM, Brickell TA, Lange RT, Carlozzi NE. Traumatic brain injury caregivers: a qualitative analysis of spouse and parent perspectives on quality of life. Neuropsychol Rehabil 2017;27:16-37.

75. Nabors N, Seacat J, Rosenthal M. Predictors of caregiver burden following traumatic brain injury. Brain Inj 2002;16:1039-50.

76. Bond AE, Draeger CR, Mandleco B, Donnelly M. Needs of family members of patients with severe traumatic brain injury. Implications for evidence-based practice. Crit Care Nurse 2003;23:63-72.

77. Kolakowsky-Hayner SA, Miner KD, Kreutzer JS. Long-term life quality and family needs after traumatic brain injury. J Head Trauma Rehabil 2001;16:374-85.

78. Roe C, Anke A, Arango-Lasprilla JC, et al. The Family Needs Questionnaire-Revised: a Rasch analysis of measurement properties in the chronic phase after traumatic brain injury. Brain Inj 2020;34:1375-83.

79. Anke A, Roe C, Sigurdardottir S, et al. Family needs at one and two years after severe traumatic brain injury: a prospective study of changes and predictors. Brain Inj 2020;34:89-97.

80. Serio CD, Kreutzer JS, Witol AD. Family needs after traumatic brain injury: a factor analytic study of the Family Needs Questionnaire. Brain Inj 1997;11:1-9.

81. Gan C, Gargaro J, Brandys C, Gerber G, Boschen K. Family caregivers' support needs after brain injury: a synthesis of perspectives from caregivers, programs, and researchers. NeuroRehabilitation 2010;27:5-18.