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ORIGINAL ARTICLE CLINICAL STUDIES

Traumatic Brain Injury and Risk of Long-Term Nursing Home Entry among Older Adults: An Analysis of Medicare Administrative Claims Data

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Abstract

Traumatic brain injury (TBI) is a leading cause of injury-related disability among older adults, and there is increasing interest in post-discharge management as this population grows. We evaluated the association between TBI and long-term nursing home (NH) entry among a nationally representative sample of older adults. We identified 207,355 adults aged ≥65 years who received a diagnosis of either a TBI, non-TBI trauma, or were uninjured between January 2008 and June 2015 from a 5% sample of Medicare beneficiaries. The NH entry was operationalized as the first NH admission that resulted in a stay ≥100 days. Time to NH entry was calculated as the difference between the NH entry date and the index date (the date of TBI, non-TBI trauma, or inpatient/outpatient visit in the uninjured group). We used cause-specific Cox proportional hazards models with stabilized inverse probability of exposure weights to model time to NH entry as a function of injury in the presence of death as a competing risk and generated hazard ratios (HR) and 95% confidence intervals (CI). After excluding beneficiaries living in a NH at index, there were 60,600 TBI, 63,762 non-TBI trauma, and 69,893 uninjured beneficiaries in the sample. In weighted models, beneficiaries with TBI entered NHs at higher rates relative to the non-TBI trauma (HR 1.15; 95% CI 1.10, 1.20) and uninjured (HR 1.67; 95% CI 1.60, 1.74) groups. Future research should focus on interventions to retain older adult TBI survivors within the community.

Keywords: head injury; nursing home entry; nursing home placement; older adult; traumatic brain injury

Introduction

Traumatic brain injury (TBI) is a major cause of death and disability in the United States among older adults aged 65 years and older,[1–3] with more than 600,000 sustaining a TBI in 2013 alone.[2] As a result of these injuries, more than 123,000 older adults were hospitalized, and 21,000 died.[2] The incidence of TBI-related emergency department visits, hospitalizations, and deaths is highest among older adults[2,4] and is increasing faster than any other age group,[2,5] at a rate that exceeds their population growth.[4] In addition to being at greater risk of TBI, older adults experience higher morbidity and mortality[6] compared with younger adults with similar TBI severity.[7–11]

After a TBI, older adults have slower recovery trajectories[12–14] and worse functional, cognitive, and psychosocial outcomes post-injury.[12,15–17] Among older adults, a study of the year after TBI found that functional

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capacity declined steadily after injury, reaching a loss of one activity of daily living (ADL) at 12 months.[18] In addition, older adults with TBI have a heavier burden of comorbid illness compared with those without TBI,[19–21] which may complicate or impede recovery.

Poor functional recovery after an acute insult to the brain can signal the end of independent living,[22,23] particularly among older adults who may have decreased physiological reserve.[24,25] Among survivors of acute TBI, older age is associated with a lower likelihood of being discharged home[5] and reduced community participation post-injury.[26] To date, however, no studies have examined the association between TBI and nursing home (NH) entry among older adults.

The exceedingly high financial, personal, and social costs of NH care have motivated interest in identifying risk factors that are associated with long-term NH entry. Given the increased emphasis on aging in place, such information could inform rehabilitation and home health policies. Thus, the objective of this study was to estimate the risk of long-term NH placement associated with an isolated TBI in a nationally representative sample of community-dwelling older Medicare beneficiaries.

Methods

Data sources and study design

The data source for this retrospective cohort study was a 5% random sample of Medicare beneficiaries obtained from the Centers for Medicare and Medicaid Services (CMS) Chronic Conditions Warehouse (CCW) for years 2007–2015. These data contain longitudinal health encounter information on beneficiaries ≥65 years and individuals <65 years with end-stage renal disease (ESRD) or recognized Social Security disabilities. There are more than 55 million beneficiaries[27] (>98% of adults aged 65 and over[28,29]) enrolled in the Medicare program today, making claims data nationally representative and one of the richest sources of utilization information in the country. It represents the Medicare-covered US population,[28] a diverse mixture of race, ethnicities, and geographical regions across the United States.

To identify beneficiaries residing in NHs, Medicare Part A data were linked to the Minimum Data Set 2.0 and 3.0 (MDS 2.0 and 3.0). The MDS is a federally mandated health status assessment of all Medicare/Medicaid certified NH residents. It provides a comprehensive assessment of each resident's functional capabilities and includes clinical assessments for residents at admission, discharge, quarterly, annually, and on any significant change in health status. It also includes dates of all assessments, admissions, and discharges.[30] The merged file of Medicare claims with the MDS consists of detailed date-specific information, which allows for tracking NH status monthly.

Coverage criteria

Continuous Medicare coverage was defined as having full, uninterrupted Medicare Parts A, B, but no C (health maintenance organization [HMO]) coverage. Participants were required to have 12 months of continuous coverage before the index date (the date of TBI, non-TBI trauma, or date of inpatient/outpatient visit in the uninjured group) and a minimum of three months of continuous coverage after the index date. Participant follow-up time continued if the continuous coverage criterion was met, up to five years post-index date.

Study participants

Participants included community-dwelling beneficiaries ≥65 years of age, meeting coverage criteria, and with a diagnosis of either a TBI, a non-TBI injury, or were uninjured between January 2008 and June 2015. Beneficiaries already living in a NH were excluded. Participants contributed follow-up time until the sooner of discontinued enrollment, NH placement, death, September 30, 2015, or five years.

Exposure

The exposure in this study was injury status, classified into three mutually exclusive levels: TBI, non-TBI trauma, and uninjured. We ensured that the injury groups were independent by excluding persons who appeared in more than one group. We chose to use only diagnoses codes in the primary position of a claim, to eliminate beneficiaries who may have had other more severe health problems that could have altered their risk of NH placement. Typically the location of claims can be indicative of the severity of injury or health problem (in the uninjured cohort).

Comparison with the non-TBI trauma beneficiaries will help disentangle the effect of an isolated TBI from the effect of traumatic injury in general while comparison with uninjured beneficiaries will provide an estimate of the overall impact of TBI on NH entry compared with the general population of Medicare beneficiaries.

TBI. This exposure category consisted of beneficiaries with an isolated traumatic injury to the head. A TBI was operationalized using the Centers for Disease Control and Prevention case definition International Classification of Disease (ICD) codes often used in epidemiologic studies.[31,32] We searched for the first claim for at least one of the following International Classification of Diseases (ICD) version 9, clinical modification (ICD-9-CM) codes for concussion (850.xx), non-specific TBIs (853.xx-854.1x), and other TBIs (800.xx, 801.xx, 803.xx, 804.xx, 851.xx-852.xx, 950.1-950.3, 959.0) between January 2008 and June 2015 in the first position of inpatient and outpatient claims.

Non-TBI trauma. This exposure category consisted of comparison beneficiaries with a traumatic injury, not involving the head. Adopting codes from the Barell Injury Diagnosis Matrix,[33] we searched for the first claim for at least one of the following ICD-9-CM codes for any of the four major injury diagnoses: torso fractures (807.0x-4x, 808.xx, 809.xx) upper extremity fractures (810.xx-818.xx), hip fractures (820.xx), and lower extremity fractures (821.xx-827.xx) between January 2008 and June 2015 in the first position of inpatient and outpatient claims. We randomly selected and frequency-matched with the TBI group on index dates and inpatient and outpatient claims.

Typically, less severe injuries are diagnosed in an outpatient setting while more severe injuries are likely diagnosed in an inpatient setting. By matching on the distribution of inpatient and outpatient claims, we attempted to ensure a similar distribution of hospitalized and non-hospitalized cases and, ultimately, injury or health problem severity. Our random sampling was conducted in a stratified manner to ensure this.

Uninjured. The uninjured exposure category included a random sample of inpatient and outpatient claims of beneficiaries aged ≥65 years, meeting continuous coverage criteria, and without a TBI or a non-TBI injury between January 2008 and June 2015. Beneficiaries in this group were selected randomly to have a frequency-matched sample of the same size and with the same distribution of inpatient and outpatient claims as the TBI group, resulting in an equivalent distribution of index dates.

Outcome

The primary outcome was long-term NH entry. The NH stays were identified based on the method described by Intrator and associates[34] and modified by Goodwin and colleagues[35] using Part A claims plus the MDS. We defined long-term NH entry as the first NH admission that resulted in a stay of ≥100 days to distinguish admissions for long-term care from admissions for short-term stays that typically occur for rehabilitation (detailed in the Supplementary Appendix). This definition is based on Medicare's policy for reimbursement (short NH stays <100 days where skilled nursing care is needed are covered by Medicare. However, Long stays ≥100 days are not covered). Time to NH entry was calculated as the difference between the index date and the date of NH admission. Beneficiaries were right censored at the time of death, at the end of follow-up, or study termination.

Covariates

Demographic, clinical characteristics, and original reason for entitlement code were obtained from administrative claims files. The CCW data also contain information on 27 common chronic comorbid conditions, with an annual flag for each condition as well as the date of the first diagnosis for that condition, based on validated algorithms that search for specific diagnostic codes within the CMS administrative claims.[36] We combined the five cancer flags to create an ''any cancer'' variable and selected to report the Alzheimer disease and related dementias flag rather than the Alzheimer disease (only) flag. We used the date of the first diagnosis to determine whether a condition was present at the index date.

Statistical analysis

We compared the baseline distribution of demographic and clinical variables by injury status, using either chi-square goodness of fit for categorical variables and analysis of variance or Kruskal-Wallis tests for continuous variables, as appropriate. We excluded all individuals who were NH-dwelling pre-injury and used stabilized inverse probability of treatment weights (IPTW) to balance covariates between exposure groups. We used a multinomial logistic regression in which the outcome variable was injury group and included the following as covariates in the model: demographic variables such as age, sex, and race; 27 common chronic conditions, and other variables such as length of follow-up and original reason for Medicare entitlement.

Given our large sample size, all covariates differed significantly across injury groups. We examined the balance of observed covariates in the weighted sample by computing standardized mean differences (the difference in means between TBI and no-TBI (non-TBI trauma and uninjured) groups divided by the overall standard deviation) on pre- and post-matched samples, following published guidelines.[37] We used a cutoff of ±0.03 for standardized differences to identify covariates that could be further adjusted for in the regression model as a form of doubly robust estimation.[38,39]

We quantified the effect of TBI on the risk of NH entry in the presence of death as a competing risk using cause-specific Cox proportional hazards models with stabilized inverse probability weights to estimate the hazard ratio (HR) of entering a NH, with 95% confidence intervals (CIs). All analyses were performed with SAS Studio Enterprise Edition 3.71 (SAS Institute, Cary, NC). This study was approved by the Institutional Review Board at the University of Maryland, Baltimore.

Results

Study cohort

Between January 2008 and June 2015, we identified 76,539 beneficiaries aged 65 years and older who had a diagnosis of TBI and met continuous coverage criteria. In the same period, we identified 201,698 trauma and 1,893,700 uninjured beneficiaries and randomly selected

76,539 from each group. To ensure the groups were mutually exclusive, we excluded 9514 (12%) of the TBI group with a trauma diagnosis, 8860 (12%) of the trauma group with a TBI diagnosis, and 5066 (7%) of the uninjured group with a TBI/trauma diagnosis. At baseline, 13,100 (6%) of the sample (11% of those with TBI, 6% of those with trauma, and 2% of the uninjured group) were living in a NH and were excluded from analyses.

Our final cohort contained 194,225 beneficiaries (60,600 with TBI, 63,762 with trauma, and 69,893 uninjured) who were predominantly female (69%) and white (86%) with an average age of 77.0 years (standard deviation [SD] 8.6; Table 1). As presented in Table 1, those with TBI were older (80.4 years [SD 8.1] vs. 78.1 [SD 8.2]) for non-TBI trauma and 71.8 [SD 7.2] years in the uninjured, $p < 0.001$) and had a higher burden of comorbidities. For example, those with TBI were significantly more likely to have hypertension (90% vs. 83% and 65%), hyperlipidemia (83% vs. 78% and 62%), ischemic heart disease (64% vs. 52% and 28%), and diabetes (42% vs. 35% and 25%) ($p < 0.001$ for all).

NH entry

Of those in the TBI group who were community dwelling at baseline, 19,064 (35%) were censored because of death, compared with 13,957 (24%) and 7615 (11%) of the trauma and uninjured groups, respectively ($p < 0.001$). Those with a TBI were more likely to enter a NH during the five-year follow-up (9% vs. 7% and 2%, $p < 0.001$). The median time to NH entry was shorter for the trauma group, 159 days (interquartile range [IQR] 763 days), than for the TBI and uninjured groups, 274 days (IQR 709 days) and 388 days (IQR 1011 days) (Table 2). Median follow-up time was shorter in the TBI group versus the control groups ($p < 0.001$).

Table 1. Baseline Characteristics of Community-Dwelling Medicare Beneficiaries ≥65 Years, by Injury Type (2008-2015), (n = 194,225)

	Total n = *194,225*	*TBI* n = *60,600*	*Trauma* n = *63,762*	*Uninjured* n = *69,893*	p
Patient characteristics					
Age (years), mean (SD)	76.5 (8.6)	80.4 (8.1)	78.1 (8.2)	71.8 (7.2)	< 0.001
Sex, n (%)					< 0.001
Female	134,575 (69)	20,007 (33)	17,167 (27)	22,506 (32)	
Male	59,680 (31)	40,593 (67)	46,595 (73)	47,387 (68)	
Race, n (%)					< 0.001
White, non-Hispanic	166,152 (86)	52,366 (86)	56,525 (89)	57,261 (82)	
Black	11,785 (6)	3404 (6)	2890 (5)	5491 (8)	
Hispanic	9450 (5)	2906 (5)	2685 (4)	3859 (6)	
Asian/Pacific Islander	3920 (2)	1216 (2)	894 (1)	1810 (3)	
American Indian/Alaska Native	951 (<1)	303 (<1)	350 (<1)	298 (<1)	
Other	1,112 (<1)	308 (<1)	290 (<1)	514 (<1)	
Unknown	885 (<1)	97 (<1)	128 (<1)	660 (<1)	
Original Reason for Medicare Entitlement, n (%)					< 0.001
Old Age and Survivors Insurance (OASI)	177,440 (91)	54,234 (90)	57,332 (90)	65,874 (94)	
Disability Insurance Benefits (DIB)	16,430 (8)	6222 (10)	6269 (10)	3939 (6)	
Other	385 (<1)	144 (<1)	161 (<1)	80 (<1)	
Clinical characteristics & comorbidities					
Alzheimer disease and related dementias	33,323 (17)	18,203 (30)	11,193 (18)	3927 (6)	< 0.001
Acute myocardial infarction	9042 (5)	4465 (7)	3437 (5)	,140 (2)	< 0.001
Anemia (ever)	100,096 (52)	42,005 (69)	37,108 (58)	20,983 (30)	< 0.001
Asthma (ever)	24,078 (12)	9972 (16)	9127 (14)	4979 (7)	< 0.001
Atrial fibrillation	31,332 (16)	15,610 (26)	11,057 (17)	4665 (7)	< 0.001
Cataracts	128,299 (66)	48,143 (79)	47,277 (74)	32,879 (47)	< 0.001
Congestive heart failure	52,943 (27)	24,889 (41)	19,634 (31)	8420 (12)	< 0.001
Chronic kidney disease	41,079 (21)	19,215 (32)	15,049 (24)	6815 (10)	< 0.001
All cancers	30,297 (16)	11,740 (19)	11,017 (17)	7540 (11)	< 0.001
Chronic obstructive pulmonary disease	49,164 (25)	20,721 (34)	19,261 (30)	9182 (13)	< 0.001
Depression	60,318 (31)	26,607 (44)	22,024 (35)	11,687 (31)	< 0.001
Diabetes	65,517 (34)	25,459 (42)	22,509 (35)	17,549 (25)	< 0.001
Glaucoma	44,536 (23)	17,264 (29)	15,829 (25)	11,443 (16)	< 0.001
Hip/pelvic fracture	7443 (4)	4304 (7)	2140 (3)	999 (1)	< 0.001
Hyperlipidemia (ever)	143,843 (74)	50,477 (83)	49,870 (78)	43,496 (62)	< 0.001
Benign prostatic hyperplasia (ever)	26,150 (13)	11,480 (19)	8333 (13)	6337 (9)	< 0.001
Hypertension (ever)	152,338 (78)	54,330 (90)	52,857 (83)	45,151 (65)	< 0.001
Acquired hypothyroidism (ever)	52,240 (27)	20,475 (34)	18,912 (30)	12,853 (18)	< 0.001
Ischemic heart disease	92,325 (48)	39,065 (64)	33,469 (52)	19,791 (28)	< 0.001
Osteoporosis	51,031 (26)	19,832 (33)	21,413 (34)	9786 (14)	< 0.001
Rheumatoid arthritis/osteoarthritis	105,366 (54)	42,487 (70)	39,453 (62)	23,426 (34)	< 0.001
Stroke/transient ischemic attack	32,493 (17)	16,628 (270	11,509 (18)	4356 (6)	< 0.001

TBI, traumatic brain injury; SD, standard deviation.

Table 2. Outcomes of Community-Dwelling Medicare Beneficiaries ≥65 Years, by Injury Type (2008-2015), (n = 194,225)

	Total n = *194,225*	*TBI* n = *60,600*	*Trauma* n = *63,762*	*Uninjured* n = *69,893*	p
Nursing home (NH) entry					
Deaths before NH entry, *n* (%)	33,021 (16)	19,064 (35)	13,957 (24)	7615 (11)	< 0.001
Incident NH entry, n (%)	12,276 (6)	6108 (9)	4740 (7)	1428 (2)	< 0.001
Time to NH entry (days), median (IQR)	246 (769)	274 (709)	159 (763)	388 (1011)	< 0.001
Follow-up (months), mean (SD)	40 (25)	35 (24)	40 (25)	44 (25)	< 0.001

TBI, traumatic brain injury; IQR, interquartile range' SD, standard deviation.

Table 3 presents the results of Cox proportional hazard models to evaluate the relation of TBI with NH entry. In the unadjusted model, we observed a higher risk of NH entry in the TBI group compared with the trauma (HR 1.47; 95% CI 1.42, 1.53) and uninjured groups (HR 5.91; 95% CI 5.57, 6.26). After adjusting for covariates, we still observed a significantly higher risk of NH entry in the TBI group compared with both the trauma (HR 1.15; 95% CI 1.10, 1.20) and uninjured (HR 1.67; 95% CI 1.60, 1.74) groups (Table 3).

Discussion

This is the first study to report on long-term NH home placement after TBI in a large, nationally representative sample of community-dwelling older adults enrolled in Medicare. In our study, TBI was associated with a 15–67% increased risk of NH entry among community-dwelling Medicare beneficiaries compared with those with non-TBI trauma and with uninjured beneficiaries. Among those with TBI, the five-year cumulative incidence of NH entry was 9%, which was higher than those with non-TBI trauma and the uninjured. Among beneficiaries with TBI, the median time to NH placement was 274 days (Table 2), suggesting that individuals with TBI may have been community dwelling for a period of time before entering the NH. Without additional information on discharge date and destination, however, we were unable to assess this further.

Aging results in a progressive decline in molecular and cellular function[40] that leads to a limited physiological reserve and a higher comorbidity burden.[25,41] Consistent with other research,[12,42,43] our findings indicated that those with TBI had a higher comorbidity burden before their injury, even when compared with older adults with non-TBI trauma. In our study sample, those with TBI were more likely to have diabetes, high blood pressure, cancer, and stroke, risk factors for NH admission.[44] Although the three exposure groups were balanced on these covariates in weighted regression analyses, residual confounding because of unequal burden of comorbidity between groups was still possible.

Time to NH entry was also much shorter in the trauma cohort, suggesting that NH admissions after a TBI come after a period of declining health while admissions after trauma may be more immediate. This could potentially be because most cases of TBI among those over 65 years are mild,[45] but without the documentation of injury severity in claims data, we were unable to assess this further.

The long-term sequelae of TBI include both cognitive and functional impairment, some of the strongest predictors of NH admission among older adults.[44] Although the association between TBI and NH placement has not been well studied among older adults, falls have been reported to result in declines in function, both from physical injury and the loss of confidence in the ability to perform functional activities,[46] ultimately increasing the risk of NH admission.[44,47]

Falls are the most prevalent mechanism of TBI[2] and also the primary cause of hip fractures among the elderly (95%).[48] Hip fracture results in significant increases in disability and nursing home admission compared with age-matched controls.[49,50] In 2008, one study reported that 35% of older adult hip fracture patients were placed in long-term NH care within one year post-fracture.[51] Another study of older adult hip fracture patients reports that 33% became permanent skilled nursing facility residents.[52] The findings from this our study, which are specific to older adult TBI survivors, report a five-year cumulative incidence of NH placement of 9%, much lower than that reported after hip fracture. Hip fracture usually requires surgery and causes an immediate drop in mobility whereas TBI generally does not.

Table 3. Cox Regression Analyses of Time to Nursing Home Entry with Death as a Competing Event, among Medicare Beneficiaries ≥65 Years (2008-2015), (n = 194,255)

	Hazard Ratio (95% CI)		
		Adjusted	
	Unadjusted	*Weighted*	*Weighted (some covariates[a])*
Non-TBI trauma	Reference	Reference	Reference
TBI	1.47 (1.42, 1.53)	1.18 (1.13, 1.23)	1.15 (1.10, 1.20)
Uninjured	Reference	Reference	Reference
TBI	5.91 (5.57, 6.29)	1.40 (1.34, 1.46)	1.67 (1.60, 1.74)

CI, confidence interval; TBI, traumatic brain injury.

[a]Adjusted for age, Alzheimer disease and related dementias, atrial fibrillation, congestive heart failure and stroke/transient ischemic attack (covariates with standardized differences ±0.03).

Older adults with stroke are perhaps most similar to those with TBI with regard to cognitive impairment. In 2018, Blackburn and coworkers[53] characterized long-term NH placement after stroke among older adult Medicare beneficiaries. They reported that within 5 years of stroke, 119 (21.3%) participants had been placed in a nursing home.[53] Lifestyle-related factors such as diabetes and hypertension have also been reported as important predictors of long-term NH admission among middle-aged and older adults.[54] In our study, those with TBI were significantly more likely than the other groups to have diabetes and hypertension at baseline, increasing their risk of NH placement even before the TBI. Although imbalances in the distribution of these comorbidities and covariates were accounted for using IPTW, there still remains a potential for residual confounding.

There are limitations to the current study. This was a secondary analysis of administrative claims data from 2008–2015. Although we had data for years 2016 and 2017 available to us, we chose to only use data before the switch from ICD-9 to ICD10 coding. Although more recent data are preferable, given the lack of literature on this topic, we believe the data can still provide an estimate of the risk of long-term NH placement associated with having a TBI. At the very least, estimates from this study can serve as a historical reference for comparison when current data become available.

Administrative claims data lack documentation of the occurrence of previous head injuries or of traditional measures of TBI severity (Glasgow Coma Scale Score, Abbreviated Injury Score), which likely have a large impact on NH placement. These are certainly important factors that impact NH placement and that would be important factors to control for in future studies. In addition, this study lacks contextual factors such as social/family support that have been associated with a 10–50% decreased likelihood of NH admission among older adults in the general population.[55]

Previous studies in younger populations suggest that home- and community-based services can substitute for long-term NH for some individuals.[56] For example, the availability of home- and community-based services is negatively associated with the rate of NH admissions among young adults and the presence of NH residents with low-care needs.[56,57] The extent to which home- and community-based services can reduce NH placement among older survivors of TBI should be explored in future studies. It is unlikely, however, that social/family support and home- and community-based services are distributed so differently in the three groups studied that they can explain differential NH admissions.

It is worth noting that we excluded beneficiaries with multiple injuries, which may underestimate the true effect size. This is less of a concern, however, among older adults who are less likely to have multiple injuries than younger persons. Last, administrative claims data are collected for billing and reimbursement purposes. Therefore, the assessment of all measures is dependent on documentation.

This is the largest study of which we are aware reporting estimates of long-term NH placement after TBI among older adults. As such, it can serve as a baseline reference for future studies and inform the development and improvement of post-discharge care services and policies. This is significant because it provides critical information on an important recovery outcome after TBI. In addition, our nationally representative dataset had an average follow-up duration of 3.3 years, and the use of a non-TBI trauma injury and an uninjured control group allowed us to disentangle the separate effects of trauma and TBI. Finally, data on NH admission were collected monthly, allowing us to determine dates of admission and length of stay more accurately.

Older adults with a TBI have a 15–67% increased risk of NH entry. Future research is needed to understand the rehabilitation needs of older adults with TBI so that resources can be directed toward keeping older adults in community settings.

Transparency, Rigor, and Reproducibility Summary

We have taken several steps to mitigate bias and ensure that results from this study are robust and reproducible. To identify TBI in Medicare administrative claims, we used the Centers for Disease Control and Prevention case definition. We adopted diagnosis codes from the Barell Injury Diagnosis Matrix to identify non-TBI trauma injuries. Nursing home stays were identified based on a validated algorithm described by Intrator et al. Chronic diseases were identified from the claims based on validated algorithms that search for specific diagnostic codes. Requiring continuous enrollment during the study period ensured that all events of interest were captured. We examined the balance of observed covariates in the weighted sample by computing standardized mean differences (the difference in means between TBI and no-TBI (non-TBI trauma and uninjured) groups divided by the overall standard deviation) on pre- and post-matched samples, following published guidelines. We further adjusted for covariates with standardized differences greater than ± 0.03 in the regression model as a form of doubly robust estimation.

Authors' Contributions

MDB: Conceptualization (lead); Methodology (lead); Data curation (lead); Formal analysis (lead); writing–original draft (lead); writing–review and editing (equal). SG: Methodology (supporting); writing–review and editing (equal). AG: Methodology (supporting); writing–review and editing (equal). JG: Methodology (supporting); writing–review and editing (equal). RK: Methodology (supporting); writing–review and editing (equal). DQ:

Methodology (supporting); writing–review and editing (equal). MS: Methodology (supporting); writing–review and editing (equal). JSA: Conceptualization (supporting); Methodology (supporting); writing–original draft (supporting); writing–review and editing (equal).

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Author Disclosure Statement

No competing financial interests exist.

Supplementary Material

Supplementary Appendix

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