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Depression among Older Adults Following Traumatic Brain Injury: A National Analysis

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Abstract

Objective—Sequelae of traumatic brain injury (TBI) include depression, which could exacerbate the poorer cognitive and functional recovery experienced by older adults. The objective of this study was to estimate incidence rates of depression following hospital discharge for TBI among Medicare beneficiaries aged ≥ 65 years, quantify the increase in risk of depression following TBI, and evaluate risk factors for incident depression post-TBI.

Design—Retrospective analysis of Medicare claims data

Participants—Medicare beneficiaries ≥ 65 years hospitalized for traumatic brain injury (TBI) during 2006–2010 who survived to hospital discharge and had no documented diagnosis of depression prior to the study period (n=67,347).

Measurement—Diagnosis of depression during the study period.

Results—The annualized incidence rate of depression per 1,000 beneficiaries was 62.8 (95% confidence interval (CI) 61.6, 64.1) pre-TBI and 123.9 (95% CI 121.6, 126.2) post-TBI. Annualized incidence rates were highest immediately following hospital discharge and declined over the twelve months post-TBI. TBI increased the risk of incident depression in men (hazard ratio (HR) 1.95; 95% CI 1.84, 2.06, Wald $\chi^2=511.4$, df=1, p < 0.001) and in women (HR 1.69; 95% CI 1.62, 1.77, Wald $\chi^2=589.3$, df=1, p < 0.001). The strongest predictor of depression post-TBI for both men and women was discharge to a skilled nursing facility: men (odds ratio (OR) 1.91; 95% CI 1.77, 2.06,

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Wald $\chi^2=277.1, df = 1, p < 0.001$), women: (OR 1.72; 95% CI 1.63, 1.83, Wald $\chi^2=324.2, df = 1, p < 0.001$).

Conclusions—TBI significantly increased the risk of depression among older adults, especially among men and those discharged to a skilled nursing facility. Results from this study will help increase awareness of the risk of depression post-TBI among older adults.

Keywords

Depression; Older Adults; Traumatic Brain Injury

Objective

Traumatic brain injury (TBI) among older adults is primarily caused by falls and results in 142,000 emergency department visits and 81,500 hospitalizations each year in the United States.¹ Hospitalization rates for TBI among older adults are more than double the rates observed in other age groups, and have increased steadily since 2001 while rates in other age groups have declined.² Sequelae of TBI include depression, which can negatively impact cognitive and functional recovery following TBI.^{3–7} Consequently, depression may exacerbate poorer outcomes experienced by older adults following TBI.^{8–12} Despite this known association between TBI and depression, little is known about the risk of depression following TBI among older adults.

Research on the prevalence of depression following TBI has reported a wide range of estimates (10%–77%), but studies focusing specifically on older adults have reported post-TBI depression prevalence between 10–42%.^{3,5,7,13–17} Previous research has centered on younger populations in which motor vehicle accidents, often associated with alcohol or substance abuse, were the primary cause of TBI.^{5,6,14,15,18} The association between alcohol abuse, a risk factor for TBI, and depression is well established, suggesting that younger individuals with TBI may have been more likely to be depressed pre-injury.^{13,14,19–21} This could have resulted in an overestimate of the risk of depression attributed to TBI. Similarly, prior studies focused on prevalent, rather than incident, cases of depression post-TBI that precluded the establishment of temporality.

Understanding the extent to which TBI independently influences the development of depression, especially among older adults, will support efforts to identify and treat those who develop depression following TBI and provide a broader perspective on sequelae of TBI. The objectives of this study were to: 1) to estimate incidence rates of depression following hospital discharge for TBI among Medicare beneficiaries aged ≥ 65 years; 2) to quantify the increase in risk of depression following TBI; and 3) to evaluate risk factors for incident depression post-TBI. TBI severity may not be associated with depression among younger adults, but this association could be different among older adults given their poorer cognitive and functional outcomes following TBI.^{5,8–13,15,19} We hypothesized that in this older adult population, factors that may be associated with TBI severity, such as length of hospital stay and discharge to a skilled nursing facility, would be associated with incident depression following TBI.

Methods

Medicare administrative data obtained from the Centers for Medicare & Medicaid Services (CMS) Chronic Condition Data Warehouse (CCW) were the primary sources of data for this study. All Medicare beneficiaries with a discharge diagnosis of TBI (International Classification of Disease, 9th Revision (ICD-9) codes 800.xx, 801.xx, 803.xx, 804.xx, 850.xx-854.1x, 950.1–950.3, 959.01) in any position on an inpatient claim between 1/1/2006 and 5/31/2010 and meeting inclusion criteria were included in the study. Inclusion criteria were age ≥ 65 years at the time of TBI, survival to hospital discharge, continuous enrollment in Medicare Parts A and B with no Part C (Medicare Advantage) enrollment for at least 6 months prior to the date of hospital admission for TBI to capture baseline comorbidities, enrollment in Medicare Parts A and B with no Part C enrollment for at least 12 months prior to the date of depression diagnosis to ensure that we are capturing incident depression, and first hospitalization for TBI. Beneficiaries covered with Medicare advantage plans are excluded from these analyses because their claims are missing from these data. New claims for TBI occurring within 14 days of a previous TBI discharge were combined to form a single hospitalization episode with an admission date reflecting the earliest TBI claim's admission date and a discharge date reflecting the latest TBI claim's discharge date.

The CCW contains information on 27 comorbid conditions, including depression.²² Depression is defined in the CCW by the presence of any of the following ICD-9 codes: 296.20, 296.21, 296.22, 296.23, 296.24, 296.25, 296.26, 296.30, 296.31, 296.32, 296.33, 296.34, 296.35, 296.36, 296.51, 296.52, 296.53, 296.54, 296.55, 296.56, 296.60, 296.61, 296.62, 296.63, 296.64, 296.65, 296.66, 296.89, 298.0, 300.4, 309.1, or 311 on any inpatient, skilled nursing facility (SNF), home healthcare, hospice, or Carrier claim. The CCW contains an annual flag for each condition as well as the date of first diagnosis for each beneficiary going back to 1999 or the date of Medicare enrollment. We defined incident depression pre-TBI as a date of first diagnosis of depression occurring at least twelve months after the start of the study observation period (1/1/2006) but before the hospital admission date for TBI. We defined incident depression post-TBI as a date of first diagnosis of depression occurring after the hospital discharge date for TBI but before the end of the study period (5/31/2010). Participants who were diagnosed with depression prior to the start of the study period (going back to 1999 or Medicare enrollment date, whichever was shorter) were excluded from this analysis.

Comorbidities were determined using CMS's CCW flagged comorbid conditions in conjunction with date of first diagnosis.²² If the date of first diagnosis of a particular chronic condition was prior to the date of first diagnosis of depression, the patient was considered to have that chronic condition. For those who did not develop depression, the date of TBI hospitalization was used to determine comorbid conditions. Based on prior research indicating an association between alcohol abuse and depression following TBI, we also created an indicator variable for alcohol abuse and dependence by searching for the following ICD-9 diagnosis codes from any claim during the study period, using the date of first diagnosis to determine if the condition was present at baseline: 291.xx, 303.xx, 305.0x, 571.0x, 571.2x, 571.3x.^{5,14,15} Beneficiaries contributed follow-up time to our study if they were enrolled in Medicare Parts A and B, with no Part C, at any time between 1/1/2006 and

5/31/2010, and met inclusion criteria. Once entered into the cohort, beneficiaries continued to contribute follow-up time until 5/31/2010 unless they were deceased, enrolled in a Medicare Advantage (Part C) plan, or were diagnosed with depression (to ensure that we only counted person time at risk). Each beneficiary could contribute between a minimum of 6 months and a maximum of 54 months follow-up time. A beneficiary could have more pre-TBI than post-TBI follow-up time depending on the timing of the TBI event.

We did not require a minimum follow-up time but rather calculated annual incidence rates of depression pre-TBI using the number of months of coverage for Medicare Parts A and B with no Part C (Medicare Advantage Plans) pre-TBI as the denominator, and number of new documented depression diagnoses pre-TBI as the numerator. Beneficiaries diagnosed with depression during the study period stopped contributing follow-up time following the diagnosis. We calculated incidence rates of depression post-TBI similarly, but excluded the person time contributed by beneficiaries diagnosed with depression pre-TBI. Annual incidence rates per 1,000 beneficiaries and 95% confidence intervals are reported.

To examine how quickly incidence rates of depression post-TBI were approaching pre-TBI rates, we calculated incidence rates within each time interval during the first year of follow-up following hospital discharge from TBI (>0 to 2 months, >2 to 4 months, >4 to 6 months, >6 to 8 months, >8 to 10 months and >10 to 12 months).

We analyzed frequencies and distributions of covariates. We compared covariates between the post-TBI incident depression cohorts and beneficiaries with no depression using chi-square (χ^2) for categorical variables and Student's T tests for continuous variables.

To determine if TBI increased the risk of depression we conducted a time-to-event analysis using Cox proportional hazard models with incident depression as the event of interest and TBI as the time-varying independent variable.²³ We modelled the time of TBI as indexed by the study entry date. Covariates that were associated with incident depression in bivariate analyses were considered for inclusion in our final regression model. We did not incorporate factors associated with the TBI hospitalization in our models because beneficiaries who developed depression pre-TBI had not yet been hospitalized. We tested potential interactions between covariates (age, sex, and race) and TBI individually in our regression model. If the Wald χ^2 p-value of an interaction term in the type three analysis was < 0.001, we stratified our analyses by the potential effect modifier to determine if hazard ratio estimates differed significantly from one another. Hazard ratios and 95% confidence intervals are reported.

To determine if factors related to the TBI hospitalization were associated with incident depression post-TBI, we used a logistic regression model and excluded all participants with a diagnosis of depression during the study period but prior to TBI. We included hospital length of stay and discharge to a SNF, along with potential confounders identified in bivariate analysis, in our final model. Odds ratios and 95% confidence intervals are reported.

Due to our large sample size, statistical significance was defined *a priori* as $p < 0.001$. All analyses were performed with SAS version 9.2 (Cary, NC). This study was approved by the Institutional Review Board of the University of Maryland, Baltimore.

Results

There were 99,954 Medicare beneficiaries aged 65 years who were hospitalized for TBI between 2006–2010, survived to hospital discharge, were continuously enrolled in Medicare Parts A and B with no Part C enrollment for at least 6 months prior to the date of hospital admission for TBI, and had at least 12 months of Medicare Parts A and B with no Part C enrollment prior to their first diagnosis of depression (if present). Of these, 32,607 (33%) had a diagnosis of depression prior to our observation start date (January 1, 2006) and were excluded from our analyses, leaving 67,347 beneficiaries in the sample. Average age (standard deviation (s.d.)) was 80.9 (8.2) years. The sample was predominantly female (60%) and white (86%), with a high prevalence of comorbidity. The most common comorbidities were ischemic heart disease (65%), heart failure (46%), and diabetes (40%). Thirty-nine percent had a TBI hospital stay of more than five days, and 37% were discharged to a skilled nursing facility (SNF).

Beneficiaries diagnosed with depression post-TBI were more likely to have Alzheimer's disease (30% vs. 25%, Pearson's $\chi^2=87.9$, $df=1$, $p<0.001$) than beneficiaries without depression. (Table 1) They were more likely to have a length of hospital stay of over five days (44% vs. 38%, Pearson's $\chi^2=256.2$, $df=3$, $p<0.001$) and to be discharged to a SNF (47% vs. 33%, Pearson's $\chi^2=884.9$, $df=1$, $p<0.001$). Beneficiaries diagnosed with depression post-TBI were more likely to be female compared to beneficiaries without depression (63% vs. 57%, Pearson's $\chi^2=125.7$, $df=1$, $p<0.001$). The groups did not differ appreciably by age (80.8 (8.0) years vs. 81.0 (8.3) years, Student's t-test $p=0.04$, Satterthwaite method $df=17,939$)).

The annualized incidence rate of depression pre-TBI per 1,000 beneficiaries was 62.8 (95% confidence interval (CI) 61.6, 64.1). Rates for women (69.7; 95% CI 68.0, 71.4) pre-TBI were 33% higher than rates in men (52.6; 95% CI 50.9, 54.5). Following TBI, the rate of incident depression increased almost two-fold (123.9; 95% CI 121.6, 126.2). Women (132.8.2; 95% CI 129.8, 135.9) continued to have higher incident rates of depression than men (111.2; 95% CI 107.9, 114.6) post-TBI. The absolute increase in the annual rate of depression post-TBI was similar in both men (59 cases/1,000 beneficiaries) and women (63 cases/1,000 beneficiaries).

Annualized incidence rates of depression per 1,000 beneficiaries spiked during the two months following hospital discharge (240.1; 95% CI 232.1, 248.5) and declined steadily during the following months. (Figure 1) During the ten-twelve month period post-hospital discharge, incidence rates had almost returned to pre-TBI rates (69.2; 95% CI 63.8, 75.0).

Age (test for interaction Wald $\chi^2=356.5$, $df=1$, $p<0.001$), sex (test for interaction Wald $\chi^2=19.0$, $df=1$, $p<0.001$), and race (test for interaction Wald $\chi^2=1,176.0$, $df=2$, $p<0.001$) significantly modified the effect of TBI on incident depression. When we stratified regression results by age (65 – < 75, 75 – < 85, > 85) and racial categories, the 95% confidence intervals of the estimated hazard ratios overlapped between groups. Because of this overlap, and the non-overlapping results observed when we stratified by sex, regression results are reported separately only for men and women. The adjusted cox proportional

hazards model included TBI, age, Alzheimer's disease and related dementias, heart failure, chronic obstructive pulmonary disease, neurologic disease, liver disease, and alcohol abuse and dependence. TBI doubled the risk of incident depression in men (adjusted hazard ratio (HR) 1.95; 95% CI 1.84, 2.06, Wald $\chi^2=511.4$, df=1, $p < 0.001$), and greatly increased the risk of incident depression in women (HR 1.69; 95% CI 1.62, 1.77, Wald $\chi^2=589.3$, df=1, $p < 0.001$).

The final logistic regression model predicting incident depression post-TBI contained the following variables: age, sex, race, length of hospital stay, Alzheimer's disease and related dementias, atrial fibrillation, lung cancer, alcohol abuse and dependence, hypertension, ischemic heart disease, liver disease, neurologic disease, stroke, rheumatoid arthritis, and discharge to a SNF. Sex was an effect modifier of the association between TBI and incident depression in our Cox models; therefore we report logistic results separately for men and women.

The strongest predictor of incident depression post-TBI for both men and women was discharge to a SNF: men (adjusted odds ratio (OR) 1.91; 95% CI 1.77, 2.06; Wald $\chi^2=277.1$, df=1, $p < 0.001$), women: (OR 1.72; 95% CI 1.63, 1.83; Wald $\chi^2=324.2$, df=1, $p < 0.001$). (Table 2) Alcohol abuse and dependence was a strong predictor of incident depression in men (OR 1.61; 95% CI 1.38, 1.89; Wald $\chi^2=34.8$, df=1, $p < 0.001$), but not in women (OR 1.14; 95% CI 0.85, 1.52; Wald $\chi^2=0.8$, df=1, $p=0.376$). Increasing length of hospital stay was a risk factor for incident depression among both sexes, with the greatest risk observed among those with a length of stay of nine or more days compared to a stay of fewer than three days: men (OR 1.31; 95% CI 1.19, 1.45; Wald $\chi^2=12.5$, df=1, $p < 0.001$), women (OR 1.21; 95% CI 1.11, 1.32; Wald $\chi^2=9.3$, df=1, $p=0.002$). Ischemic heart disease was also predictive of incident depression post-TBI in men (OR 1.14; 95% CI 1.05, 1.23; Wald $\chi^2=9.5$, df=1, $p=0.002$) and women (OR 1.12; 95% CI 1.06, 1.18; Wald $\chi^2=14.4$, df=1, $p < 0.001$).

Conclusions

In this national sample of adults aged ≥ 65 years, TBI significantly increased the risk of depression. Incidence rates of depression spiked immediately following hospital discharge and decreased over the year following TBI. Discharge to a SNF and increasing length of hospital stay were strong predictors of incident depression post-TBI. In men, baseline alcohol abuse and dependence was a significant risk factor for incident depression following TBI.

To our knowledge, this is the first study of rates of incident depression following TBI among older adults, although the prevalence of depression following TBI has been previously reported.^{3,5,7,13–17} Medicare beneficiaries with TBI are older and have a greater burden of comorbid illness, including a higher prevalence of depression pre-TBI, compared to the overall Medicare cohort. Hence, reporting the prevalence of depression post-TBI may result in an exaggerated estimate of the impact of TBI on development of depression. For example, 33% of Medicare beneficiaries with TBI were diagnosed with depression prior to our study period and excluded from analyses. During the same period, the prevalence of

depression among Medicare beneficiaries was less than half that number (range 12%–14%).²⁴

TBI increased the relative risk of depression in men more than in women, although the absolute risk of depression post-TBI remained higher in women. This is not surprising since incidence rates of depression were higher in women pre-TBI, and depression is more common among women.^{25,26} The assessment of gender differences in the prevalence of depression following TBI has focused on prevalent cases in a younger population and been hampered by small sample size, leading to inconsistent results.^{3,27,28}

Discharge to a SNF significantly increased the risk of depression in both men and women post-TBI. Increasing length of hospital stay was also associated with elevated risk of depression. These two variables may be associated with TBI injury severity, which was not directly measured in this study. Prior studies have reported mixed results regarding the association between TBI severity and depression.^{5,19,27–30}

Alcohol abuse or dependence was associated with increased risk of depression among men, but not among women following TBI. This association has been previously observed; however, its limitation to men has not been reported.^{5,14,15} Other observed associations between comorbid illness (e.g., dementia, ischemic heart disease) and incident depression post-TBI are consistent with prior literature on depression.^{25,31,32}

When interpreting these results, consideration should be given to the following limitations. This study only captures depression diagnoses documented in administrative claims, but the potential effect of this on the results is unclear. In general, depression is underdiagnosed and under-recorded, but after suffering TBI, patient-physician contact is increased and could potentially lead to increased diagnoses. This view is supported by our observation that diagnoses of depression spiked during the two months following hospital discharge, the period when beneficiaries might be in a SNF or closely monitored. Secondly, neither TBI nor depression severity was measured in this study. Length of hospital stay and discharge to a skilled nursing facility may be associated with TBI severity, but they may also reflect severity of other injuries, lack of social supports, potential for rehabilitation, or placement options in this elderly multimorbid population.. Future studies among older adults should incorporate measures of both TBI and depression severity. Finally, functional ability measures such as the Glasgow outcomes scale, which may be associated with depression, were not available in this study.

Still, this is the first study to report national estimates of depression incidence following TBI, to quantify the increased risk of depression associated with TBI, and to identify predictors of incident depression post-TBI among older adults. The sustained increased risk of depression following TBI has important implications for improving outcomes among older adults. Results from this study will help increase awareness of the risk of depression post-TBI among older adults. Further research is needed to determine the efficacy of different treatment modalities for depression among older adults with TBI, as well as the impact of depression treatment on long term outcomes post-TBI.

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References

1. Faul, M.; Xu, L.; Wald, MM.; Coronado, V. Traumatic Brain Injury in the United States: Emergency Department Visits, Hospitalizations and Deaths, 2002–2006. Atlanta, Georgia: Centers for Disease Control and Prevention, National Center for Injury Prevention and Control; 2010. Available at: http://www.cdc.gov/traumaticbraininjury/pdf/blue_book.pdf [Accessed 11/19/13]
2. Centers for Disease Control and Prevention. [Accessed 4/22/14] Rates of TBI-related Hospitalizations by Age Group — United States, 2001–2010. Retrieved from http://www.cdc.gov/traumaticbraininjury/data/rates_hosp_byage.html
3. Rosenthal M, Christensen BK, Ross TP. Depression Following Traumatic Brain Injury. Arch Phys Med Rehabil. 1998; 79:90–103. [PubMed: 9440425]
4. Rapoport MJ, Kiss A, Feinstein A. The Impact of Depression on Outcome Following Mild-to-Moderate Traumatic Brain Injury in Older Adults. Journal of Affective Disorders. 2006; 92:273–276. [PubMed: 16504305]
5. Dikmen SS, Bombardier CH, Machamer JE, Fann JR, Temkin NR. Natural History of Depression in Traumatic Brain Injury. Arch Phys Med Rehabil. 2004; 85:1457–1464. [PubMed: 15375816]
6. Jorge RE, Robinson RG, Starkstein SE, Arndt SV. Influence of Major Depression on 1-Year Outcome in Patients with Traumatic Brain Injury. J Neurosurg. 1994; 81:726–733. [PubMed: 7931619]
7. Fedoroff JP, Starkstein SE, Forrester AW, Geisler FH, Jorge RE, Arndt SV, Robinson RG. Depression in Patients with Acute Traumatic Brain Injury. Am J Psychiatry. 1992; 149:918–923. [PubMed: 1609872]
8. Rapoport MJ, Herrmann N, Shammi P, Kiss A, Phillips A, Feinstein A. Outcome after traumatic brain injury sustained in older adulthood: a one-year longitudinal study. Am J Geriatr Psychiatry. 2006; 14(5):456–65. [PubMed: 16670250]
9. Livingston DH, Lavery RF, Mosenthal AC, Knudson MM, Lee S, Morabito D, Manley GT, Nathens A, Jurkovich G, Hoyt DB, Coimbra R. Recovery at One Year Following Isolated Traumatic Brain Injury: A Western Trauma Association Prospective Multicenter Trial. J Trauma. 2005; 59:1298–1304. [PubMed: 16394900]
10. Utomo WK, Gabbe BJ, Simpson PM, Cameron PA. Predictors of In-Hospital Mortality and 6-month Functional Outcomes in Older Adults after Moderate to Severe Traumatic Brain Injury. Injury. Int J Care Injured. 2009; 4:973–977.
11. Selassie AW, Zalosnja E, Langlois JA, Miller T, Jones P, Steiner C. Incidence of Long-term Disability Following Traumatic Brain Injury Hospitalization, United States, 2003. J Head Trauma Rehabil. 2008; 23:123–131. [PubMed: 18362766]
12. Blazer DG. Depression in Late Life: Review and Commentary. Journal of Gerontology: Medical Sciences. 2003; 58(3):249–265.
13. Rapoport MJ. Depression Following Traumatic Brain Injury: Epidemiology, Risk Factors and Management. CNS Drugs. 2012; 26(2):111–121. [PubMed: 22296315]
14. Bombardier CH, Fann JR, Temkin NR, Esselman PC, Barber J, Dikmen SS. Rates of Major Depressive Disorder and Clinical Outcomes Following Traumatic Brain Injury. JAMA. 2010; 303(19):1938–1945. [PubMed: 20483970]

15. Fann JR, Burington B, Leonetti A, Jaffe K, Katon WJ, Thompson RS. Psychiatric Illness Following Traumatic Brain Injury in an Adult Health Maintenance Organization Population. *Arch Gen Psychiatry*. 2004; 61(1):53–61. [PubMed: 14706944]
16. 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 Rehab*. 1996; 177:883–888.
17. Menzel JC. Depression in the Elderly After Traumatic Brain Injury: A Systematic Review. *Brain Injury*. 2008; 22(5):375–380. [PubMed: 18415717]
18. Jorge RE, Startkstein SE. Pathophysiologic Aspects of Major Depression Following Traumatic Brain Injury. *J Head Trauma Rehabil*. 2005; 20(6):475–487. [PubMed: 16304485]
19. Jorge RE, Robinson RG, Moser D, Tateno A, Crespo-Facorro B, Arndt S. Major Depression Following Traumatic Brain Injury. *Arch Gen Psychiatry*. 2004; 61:42–50. [PubMed: 14706943]
20. Grant BF, Harford TC. Comorbidity between DSM-IV alcohol use disorders depression: results of a national survey. *Drug and Alcohol Dependence*. 1995; 39:197–206. [PubMed: 8556968]
21. Regier DA, Farmer ME, Rae DS, Locke BZ, Keith SJ, Judd LL, Goodwin FK. Comorbidity of Mental Disorders With Alcohol and Other Drug Abuse. *JAMA*. 1990; 264:2511–2518. [PubMed: 2232018]
22. Centers for Medicare and Medicaid Services Chronic Condition Data Warehouse. [Accessed 11/18/13] Available at: <http://www.ccwdata.org/web/guest/condition-categories>
23. Allison, PD. Survival Analysis using SAS: A Practical Guide. Vol. Chapter 5. Cary, NC: SAS Institute; 1995.
24. Centers for Medicare and Medicaid Services Chronic Condition Data Warehouse. [Accessed 11/18/13] Available at: https://www.ccwdata.org/cs/groups/public/documents/document/wls_ucm1-000774.pdf
25. Blazer D, Burchett B, Service C, George LK. The Association of Age and Depression Among the Elderly: An Epidemiologic Exploration. *Journal of Gerontology: Medical Sciences*. 1991; 46(6):M210–215.
26. Hasin DS, Goodwin RD, Stinson FS, Grant BF. Epidemiology of Major Depressive Disorder: Results from the National Epidemiologic Survey on Alcoholism and Related Conditions. *Arch Gen Psychiatry*. 2005; 62:1097–1106. [PubMed: 16203955]
27. Demakis GJ, Hammond FM, Knotts A. Prediction of Depression and Anxiety 1 Year After Moderate-Severe Traumatic Brain Injury. *Applied Neuropsychology*. 2010; 17:183–189. [PubMed: 20799109]
28. Bay E, Sikorskii A, Saint-Arnault D. Sex Differences in Depressive Symptoms and Their Correlates after Mild-to-Moderate Traumatic Brain Injury. *Journal of Neuroscience Nursing*. 2009; 41(6):298–309. [PubMed: 19998681]
29. Fann JR, Hart T, Schomer KG. Treatment for Depression after Traumatic Brain Injury: A Systematic Review. *Journal of Neurotrauma*. 2009; 26:2383–2402. [PubMed: 19698070]
30. Hoge CW, McGurk D, Thomas JL, Cox AL, Engel CC, Castro CA. Mild Traumatic Brain Injury in U.S. Soldiers Returning from Iraq. *N Engl J Med*. 2008; 358(5):453–463. [PubMed: 18234750]
31. Fiske A, Wetherell JL, Gatz M. Depression in Older Adults. *Annu Rev Clin Psychol*. 2009; 5:363–389. [PubMed: 19327033]
32. Beekman ATF, Penninx BWJH, Deeg DJH, Ormel J, Braam AW, van Tilburg W. Depression and Physical Health in Later Life: Results from the Longitudinal Aging Study Amsterdam (LASA). *Journal of Affective Disorders*. 1997; 46:219–231. [PubMed: 9547118]

Figure 1.

Annualized incidence rates per 1,000 within time intervals over the year following hospital discharge for traumatic brain injury among Medicare beneficiaries aged 65, n=57,660

*Pre-TBI rate given for comparison

Table 1

Characteristics of Medicare Beneficiaries with Traumatic Brain Injury 2006–2010, by Incident Depression Status, n=67,347

Characteristic	Depression pre-TBI N=9,687	Depression post-TBI N=11,441	No Depression N=46,219	P-Value ¹
Mean age (years) (standard deviation)	80.9 (8.2)	80.8 (8.0)	81.0 (8.3)	0.04
Sex, n (%)				< 0.001
Female	6,423 (66)	7,210 (63)	26,460 (57)	
Male	3,264 (34)	4,231 (37)	19,759 (43)	
Race ² , n (%)				< 0.001
White	8,571 (88)	9,979 (87)	39,079 (85)	
Black	472 (5)	693 (6)	3,208 (7)	
Other	644 (7)	769 (7)	3,932 (8)	
History of comorbid disease, n (%)				
Alzheimer's and related dementias	5,038 (52)	3,404 (30)	11,759 (25)	< 0.001
Heart failure	5,281 (55)	5,173 (45)	20,562 (44)	0.16
Chronic obstructive pulmonary disease	3,995 (41)	3,840 (34)	14,480 (31)	< 0.001
Diabetes	4,335 (45)	4,633 (40)	17,942 (39)	0.001
Atrial fibrillation	2,902 (30)	3,081 (27)	12,489 (27)	0.84
Chronic Kidney Disease	3,389 (35)	2,927 (26)	11,961 (26)	0.52
Ischemic heart disease	6,994 (72)	7,595 (66)	29,370 (64)	< 0.001
Stroke/transient ischemic attack	3,617 (37)	3,446 (30)	12,233 (26)	< 0.001
Liver disease	970 (10)	469 (4)	1,825 (4)	0.46
Neurologic disease	1,994 (21)	1,514 (13)	4,992 (11)	< 0.001
Ethanol abuse	397 (4)	312 (3)	867 (2)	< 0.001
Discharge to Skilled Nursing Facility, n(%)	4,431 (46)	5,427 (47)	15,053 (33)	< 0.001
Length of stay ³ , n(%)				< 0.001
0–2 days	2,400 (25)	2,262 (20)	12,380 (27)	
3–5 days	3,745 (39)	4,186 (37)	16,242 (35)	
6–8 days	1,474 (15)	1,914 (17)	6,844 (15)	
9 or more days	2,068 (21)	3,079 (27)	10,753 (23)	

¹ P-value reflects comparison between post-TBI depression and no depression cohorts using Pearson's χ^2 (1 degree of freedom except where noted) = 0.04–885. Student's t-tests for age (Satterthwaite method df=17,939).

² Degrees of freedom = 2

³ Degrees of freedom = 3

Adjusted Odds Ratios (95% confidence intervals) of Incident Depression following TBI among Medicare Beneficiaries who were not Diagnosed with Depression Prior to TBI by Sex, n=57,660

Table 2

Characteristic	Women, n=33,670	Wald χ^2 , p-value	Men, n=23,990	Wald χ^2 , p-value
Age in years	0.98 (0.98, 0.98)	138.9, < 0.001	0.98 (0.98, 0.99)	54.6, < 0.001
Length of hospital stay				
0–2 days	reference		reference	
3–5 days	1.11 (1.03, 1.19)	0.4, 0.531	1.21 (1.09, 1.33)	0.3, 0.127
6–8 days	1.18 (1.08, 1.30)	3.5, 0.062	1.25 (1.12, 1.41)	2.3, 0.564
>8 days	1.21 (1.11, 1.32)	9.3, 0.002	1.31 (1.19, 1.45)	12.5, < 0.001
Race				
White	reference		reference	
Black	0.71 (0.63, 0.7)	14.8, < 0.001	0.89 (0.78, 1.01)	0.2, 0.628
Other	0.81 (0.73, 0.90)	0.4, 0.546	0.74 (0.65, 0.84)	12.4, < 0.001
Alzheimer's and related dementias	1.17 (1.10, 1.24)	25.2, < 0.001	1.19 (1.10, 1.29)	17.4, < 0.001
Atrial fibrillation	0.92 (0.86, 0.97)	7.7, 0.005	0.94 (0.87, 1.02)	2.3, 0.131
Chronic kidney disease	0.92 (0.87, 0.98)	6.4, 0.011	0.95 (0.88, 1.03)	1.6, 0.213
Lung cancer	0.83 (0.67, 1.02)	3.1, 0.077	0.75 (0.59, 0.96)	5.2, 0.022
Alcohol abuse and dependence	1.14 (0.85, 1.52)	0.8, 0.376	1.61 (1.38, 1.89)	34.8, < 0.001
Hypertension	1.07 (0.98, 1.18)	2.1, 0.147	1.18 (1.06, 1.31)	9.0, 0.003
Ischemic heart disease	1.12 (1.06, 1.19)	14.4, < 0.001	1.14 (1.05, 1.23)	9.5, 0.002
Liver disease	0.80 (0.68, 0.93)	8.2, 0.004	0.97 (0.83, 1.14)	0.1, 0.719
Neurologic disease	1.14 (1.05, 1.25)	8.6, 0.003	1.07 (0.96, 1.18)	1.5, 0.218
Rheumatoid arthritis	1.22 (1.15, 1.29)	42.8, < 0.001	1.15 (1.07, 1.23)	14.5, < 0.001
Stroke	1.05 (0.98, 1.11)	1.9, 0.174	1.16 (1.07, 1.26)	12.9, < 0.001
Discharge to skilled nursing facility	1.72 (1.63, 1.83)	324.2, < 0.001	1.91 (1.77, 2.06)	277.1, < 0.001

I
df=1