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Utilization and Costs of Health Care after Geriatric Traumatic Brain Injury

Hilaire J. Thompson,[1,2] Sharada Weir,[3] Frederick P. Rivara,[2] Jin Wang,[2] Sean D. Sullivan,[4] David Salkever,[5] and Ellen J. MacKenzie[6]

Abstract

Despite the growing number of older adults experiencing traumatic brain injury (TBI), little information exists regarding their utilization and cost of health care services. Identifying patterns in the type of care received and determining their costs is an important first step toward understanding the return on investment and potential areas for improvement. We performed a health care utilization and cost analysis using the National Study on the Costs and Outcomes of Trauma (NSCOT) dataset. Subjects were persons 55–84 years of age with TBI treated in 69 U.S. hospitals located in 14 states ($n=414$, weighted $n=1038$). Health outcomes, health care utilization, and 1-year costs of care following TBI in 2005 U.S. dollars were estimated from hospital bills, patient surveys, medical records, and Medicare claims data. The subjects were further analyzed in three subgroups (55–64, 65–74, and 75–84 years of age). Unadjusted cost models were built, followed by a second set of models adjusting for demographic and pre-injury health status. Those in the oldest category (75–84 years) had significantly higher numbers of re-hospitalizations, home health care visits, and hours per week of unpaid care, and significantly lower numbers of physician and mental health professional visits than younger age groups (age 55–64 and 65–74 years). Significant age-related differences were seen in all health outcomes tested at 12 months post-injury except for incidence of depressive symptoms. One-year total treatment costs did not differ significantly across age categories for brain-injured older adults in either the unadjusted or adjusted models. The unadjusted total mean 1-year cost of care was $77,872 in persons aged 55–64 years, $76,903 in persons aged 65–74 years, and $72,733 in persons aged 75–84 years. There were significant differences in cost drivers among the age groups. In the unadjusted model index hospitalization costs and inpatient rehabilitation costs were significantly lower in the oldest age category, while outpatient care costs and nursing home stays were lower in the younger age categories. In the adjusted model, in addition to these cost drivers, re-hospitalization costs were significantly higher among those 75–84 years of age, and receipt of informal care from friends and family was significantly different, being lowest among those aged 65–74 years, and highest among those aged 75–84 years. Identifying variations in care that these patients are receiving and determining the costs versus benefits is an important next step in understanding potential areas for improvement.

Key words: head injury; health services; informal care outcome

Introduction

Traumatic brain injury (TBI) affects more than 1.7 million persons in the U.S. each year (Faul et al., 2010). Within those experiencing TBI, there is a growing population of concern, namely older adults. More than 323,000 TBIs occur annually among adults 55 and older in the U.S., the primary cause of which is falls (Faul et al., 2010). It is estimated that 30–40% of community-dwelling older adults experience a fall at least once a year, and of those who fall, up to 10% experience a significant injury such as a TBI (Michael et al., 2010). The incidence of geriatric TBI continues to increase, despite a

[1]Biobehavioral Nursing and Health Systems, [2]Harborview Injury Prevention and Research Center, University of Washington, Seattle, Washington.
[3]Center for Health Policy and Research, University of Massachusetts, Shrewsbury, Massachusetts.
[4]Pharmaceutical Outcomes Research and Policy Program, University of Washington, Seattle, Washington.
[5]Department of Public Policy, University of Maryland, Baltimore County, Baltimore, Maryland.
[6]Bloomberg School of Public Health, Johns Hopkins University, Baltimore, Maryland.

focus on injury prevention in the Healthy People 2010 initiatives. Even after adjusting for increased numbers of adults aging into the over-65 cohort, from 2002 to 2006 emergency department visits for TBI in older adults increased by 46%, and hospitalization rates increased by 34% (Faul et al., 2010), thus this is a significant and growing public health issue.

The costs of treating injury in the older adult population are high. It has recently been reported that overall Medicare service use in older adults following an unintentional injury (i.e., fracture, sprain, or burn) remains elevated for more than 2 years post-injury (Carter and Porell, 2011). In the study by Carter and Porell, the average cost of health care in traumatically-injured older adults increased from $681 in the month prior to injury to $4262 during the month of injury and $1092 in subsequent months post-injury. In 2003, the aggregate hospital charges for treating TBI in patients 65 years of age and older in the U.S. exceeded $2.2 billion (Thompson et al. 2006). Although prior studies have examined service utilization following TBI, they have either been drawn only from samples of patients receiving acute rehabilitative services (Phillips et al., 2004), or have excluded older adults (Hodgkinson et al., 2000). Our review of the literature has found that to date, there has not been a systematic examination of the use of health care services and the cost of health care provided to older patients with TBI. To address this gap, this study sought to: (1) describe health outcomes following geriatric TBI; (2) describe health care use following geriatric TBI; and (3) determine the 1-year costs of geriatric TBI care.

Methods

Study design and setting

The current investigation is a study of health care utilization and costs using data from the National Study on the Costs and Outcomes of Trauma (NSCOT), a multicenter, prospective cohort study of outcomes following traumatic injury conducted in 69 hospitals in 14 states in the U.S. (MacKenzie et al., 2006). The study protocol was approved by the institutional review boards at the participating centers. Patients were eligible for NSCOT if they were between 18 and 84 years of age, arrived alive at a participating hospital, and had at least one injury of 3 or higher on the Abbreviated Injury Scale ($n = 18{,}198$). A detailed description of the enrollment and data collection procedures has been previously published (MacKenzie et al., 2007). Briefly, a group of patients who were discharged alive ($n = 8021$) were selected for post-injury follow-up interviews, and all patients who died in hospital ($n = 1438$) were included in the sample, using a quota sampling strategy. This strategy was used to enroll sufficient numbers of patients across age groups, and to enable even distribution across hospital type and by injury factors (severity and principal body region injured).

To correctly represent the population, this sampling strategy required data to be weighted according to the population of eligible patients because (1) only a sample of patients who were discharged alive was selected, whereas all patients who died in-hospital were included, and (2) not all selected patients were enrolled. The weights consisted of the reciprocal product of the probability of being selected for the study, and the probability of being enrolled and having complete data given selection. The actual number of subjects (n) and the weighted number (wn) are presented for all analyses.

Participants

Subjects for the current study were identified from the NSCOT dataset and defined as persons 55–84 years of age with a diagnosis of TBI (International Classification of Diseases, Ninth Revision, Clinical Modification [ICD-9-CM] codes 800.00–801.9, 803.0–804.9, 850.0–854.1, or 959.01; Coronado et al., 2005), treated in 69 hospitals located in 14 states in the U.S. ($n = 414/wn = 1038$). We chose 55 as the lower age boundary for the present study because (1) this is the age we found to be the inflection point for when trauma mortality increases (MacKenzie et al., 2006; Mullins et al., 1998), and (2) it is the recommended older age categorization per the Guidelines for Field Triage (Sasser et al., 2012).

Variables and data sources

Demographic information was extracted from the medical record to include age, gender, marital, and insurance status. Pre-injury health status was operationalized using the number of difficulties in Katz activities of daily living, and Lawton instrumental activities of daily living (ADL/IADL), pre-injury comorbid health conditions per the Charlson index (Charlson et al., 1987), and presence of depression diagnosis in response to a self-report question: "Before your injury, did a doctor ever tell you that you had depression?" Variables measured for injury severity included pupillary response and Glasgow Coma Score-motor component (GCS-M) first reported in the emergency department, maximal Abbreviated Injury Scale score (AIS) for the head, Injury Severity Score (ISS; Baker et al., 1974), and presence of midline shift on head computed tomography (CT) scan. Mechanism of injury and discharge disposition were also extracted.

Health outcomes at 1 year post-injury were obtained from patient/proxy interviews and included functional health status as measured by the number of ADL/IADL difficulties, health-related quality of life per the Medical Outcomes Survey Short Form-36 (MOS SF-36; Findler et al., 2001), the presence of depression post-injury (as measured by the Center for Epidemiologic Studies Depression Scale-Revised; Eaton et al., 2004; Zatzick et al., 2008), and cognitive ability (as measured by the Sickness Impact Profile cognitive function subscore; Bergner et al., 1981). Scores for the SF-36 range from a low of 0 ("poor health") to a high of 100 ("good health") with a norm of 50. Health service utilization was determined at 1 year post-injury, and was obtained from patient-reported data at 3- and 12-month interviews, and verified by available Medicare records. If a subject was unable to respond for self at the 3- or 12-month interview due to health status, a proxy interview was conducted. Utilization outcomes of interest included: (1) the number of hospitalizations/nursing home stays post-index hospitalization; (2) the number of physician or other health professional visits; (3) the number of mental health professional visits; (4) the number of physical therapy/occupational therapy visits; (5) receipt of paid home health care services; and (6) receipt of care from friends or family.

One-year costs of care were estimated from a combination of data sources: hospital bills, patient surveys, medical records, and Medicare claims. Details regarding the methods on how these cost estimates were derived have been previously published (Weir et al., 2010). Individual costs were estimated for: (1) pre-index hospital care (transportation and transferring emergency department services); (2) index hospitalization; (3) rehospitalizations; (4) inpatient rehabilitation; (5) skilled nursing facility stays; (6) post-hospitalization outpatient care (physician and mental health professional visits, home health, and physical and occupational therapy); and (7) informal care from friends and family. These costs were then summed to assess total 1-year treatment costs.

Statistical analysis

Chi-square analyses were used to explore differences among age groups (55–64, 65–74, and 75–84 years of age) with respect to baseline characteristics. One-year post-injury costs in 2010 U.S. dollars were determined for all subjects using general linear models (GLM), as gamma regression allows for handling of (right) skewed data (Blough and Ramsey, 2000). Unadjusted models were first developed, and then a second set of models were developed adjusting for demographic, pre-injury functional status and premorbid health. Data at the 1-year time point were available for 80% of subjects. Statistical analyses were performed using SAS 9.2 (SAS Institute, Cary, NC) and Stata 10 (StataCorp, College Station, TX).

Results

There were 414 older adult subjects with TBI in the present study ($wn=1038$). Table 1 provides information on demographics and baseline characteristics. The proportion of males exceeded females in all categories except in the oldest age category (75–84 years). The observed rates of comorbid disease, pre-injury functional deficits, and presence of midline shift on head CT in persons 75–84 years of age were higher in comparison to the younger age groups (55–64 and 65–74 years). Discharge to home occurred less frequently as age increased, while discharge to a rehabilitation or skilled nursing facility increased.

Table 2 shows the health outcomes of older adults at 12 months post-TBI as a group and by age subcategories. Age category was significantly related to all measured outcomes except for incidence of depressive symptoms. Physical functioning as measured by both the physical component summary (PCS) of the SF-36, and number of ADL/IADL difficulties was significantly worse in those aged 75–84 years than in those aged 55–64 or 65–74 years. The SF-36 mental component summary (MCS) and the SF-6D health preference measure scores were highest in those aged 65–74 years compared to the other two age groups. Cognitive ability was significantly lower in the oldest group (75–84 years) in comparison to those aged 65–74 years.

Table 3 shows the heath care utilization post-index hospitalization in the first year following injury. In general, there were significant differences in type and amount of services received across age groups. Persons aged 75–84 years had higher numbers of re-hospitalization or nursing home stays, home health care visits, and average number of hours of unpaid care from friends or family, than those aged 55–64 or 65–74 years. Further, the oldest group received significantly fewer injury-related physician visits or general mental health visits. In this sample, there were no mental health visits related to injury in any of the age groups examined.

Total per-patient 1-year treatment costs for geriatric TBI were not significantly different across age groups in either the unadjusted model ($p=0.88$; Table 4), or the model adjusting for demographic and pre-injury health and functional variables ($p=0.97$; Table 5). However, in both models, the costs across age groups differed significantly by categories of health care by service (Tables 4 and 5). Index hospitalization was the primary cost driver in the younger age group (those aged 55–64 years), with a mean cost of $31,804 (Table 4). This difference in index hospitalization costs was also seen in the adjusted model (Table 5). This is in contrast to those in the oldest category (75–84 years), in whom costs were equally related to index hospitalization costs ($15,632), and post-index hospitalization care, including rehospitalization costs in the year post-injury ($13,953), and skilled nursing facility care ($13,155; Table 4). Similar differences in rehospitalization and skilled nursing facility costs were seen in the adjusted model in persons aged 75–84 years (Table 5). The mean costs of post-index hospitalization outpatient care were significantly lower in the youngest group in both the unadjusted and adjusted models, $5406 and $4258 respectively, compared to the two older age categories. The costs of inpatient rehabilitation were found to be significantly higher in the younger age categories (55–64 years and 65–74 years) compared to the oldest category in the unadjusted model (Table 4). When the model was adjusted for demographic and injury-related factors, these differences in costs were no longer significant (Table 5). Only in the model that adjusted for demographic and pre-injury health and function were there significant differences in the mean cost of informal care from friends or family, with the provision of care to both those aged 55–64 years and those 75–84 years being significantly higher than those aged 65–74 years (Table 5).

Discussion

In this study, we sought to perform a cost analysis of geriatric TBI care in the U.S. in order to describe costs per person and to analyze cost drivers.

We found that the average unadjusted hospital costs for older adults ranged from $15,632 to $31,804, depending on age category. These costs are comparable to those reported from a recent study by McGarry and colleagues (2002), who reported average hospitalization costs in 1999 dollars by severity of injury following TBI (range $8189–33,537). In their sample, the majority of persons with severe injury were over 65 years of age. This is in contrast to a report of persons with motor vehicle-related TBI in Ohio, who had estimates higher than those in the present study ($46,441). The average age in that sample was much younger: 37.2 years (Rochette et al., 2009). Thus the differences seen in cost estimates may be related to differences in clinical management of TBI across age groups, differences in treatment due to the primary cause of injury (fall versus motor vehicle accident), or temporal differences in costs.

Other studies of all-cause trauma have reported that the cost of care of older adults is much higher compared to their younger counterparts (Newell et al., 2009). In contrast, we found that 1-year treatment costs were not significantly different across age categories for older adults following TBI. However, our study did reveal significant differences in the types and amount of services received across age groups, as well as differences in the drivers of the total costs of care.

Differences in health care utilization were not seen between the two younger age categories (55–64 versus 65–74 years), but were seen between the oldest age category and

Table 1. Sample Characteristics of Geriatric Traumatic Brain Injury Patients (n=414/wn=1038)

Characteristic	All patients, n=414 (wn=1038) %	Age 55–64 years, n=105 (wn=376) %	Age 65–74 years, n=159 (wn=348) %	Age 75–84 years, n=150 (wn=314) %	p Value
Male	59.3	68.9	61.0	45.8	0.002
Race/ethnicity					0.41
Hispanic	11.3	13.6	13.0	6.7	
Non-Hispanic, white	76.7	72.1	76.2	82.7	
Non-Hispanic, non-white	12.0	14.3	10.8	10.6	
Insurance status					<0.0001
None	8.7	16.8	5.2	3.0	
Medicare Only	17.7	6.0	26.7	22.0	
Medicare plus private	46.7	7.1	65.5	73.4	
Private only	22.3	61.6			
Medicaid	2.4	4.9	1.4	0.5	
Other	2.1	3.6	1.2	1.1	
Marital status at injury					<0.0001
Single	7.5	12.6	5.1	4.2	
Married/partnered	59.7	58.0	70.9	49.3	
Widowed	17.3	4.4	12.7	37.9	
Divorced/separated	15.5	25.0	11.3	8.7	
Maximum AIS-head					0.95
<3	14.8	15.6	13.9	14.8	
≥3	85.2	84.4	86.1	85.2	
Injury Severity Score, mean (SD)	18.2 (13.1)	19.2 (17.0)	17.9 (11.7)	17.5 (10.9)	0.10
Isolated TBI	23.5	20.7	21.4	29.2	0.23
First ED Glasgow Coma Score, total mean (SD)	13.7 (4.9)	13.4 (7.0)	13.6 (4.6)	14.2 (3.1)	0.12
First ED Glasgow Coma Score-motor					0.005
6	89.8	86.4	87.7	96.2	
4–5	2.8	2.5	5.4	0.1	
2–3	0.4	-	0.4	0.8	
1, not paralyzed	1.9	1.5	2.8	1.5	
1, paralyzed	5.1	9.6	3.7	1.4	
Pupillary response unequal and non-reactive	3.5	2.7	3.8	4.0	0.78
Midline shift on CT	7.2	3.1	6.1	13.5	0.002
Number of pre-injury ADL difficulties					<0.0001
0	84.9	94.2	87.0	71.5	
≥ 1	15.1	5.8	13.0	28.5	
Number of pre-injury IADL difficulties					<0.0001
0	84.5	91.3	86.3	74.2	
≥ 1	15.5	8.7	13.7	25.8	
Pre-injury Charlson score					<0.0001
0	46.1	63.6	42.9	28.8	
1	25.8	20.1	28.4	29.6	
2	13.1	8.7	14.5	17.0	
≥ 3	15.0	7.6	14.2	24.6	
Discharge disposition					<0.0001
Home	53.3	61.7	55.7	40.5	
Rehabilitation	30.1	28.0	29.6	33.2	
Skilled nursing Facility/nursing home/residential facility	13.1	5.9	10.4	24.6	
Others	3.6	4.5	4.3	1.7	
History of depression before injury					0.03
No	81.8	80.6	85.4	79.2	
Yes, not on medication	14.5	17.0	8.0	18.9	
Yes, on medication	3.7	2.4	6.6	1.9	

Data are presented as percentages (%) unless otherwise noted.

ED, emergency department; AIS, Abbreviated Injury Scale; SD, standard deviation; wn, weighted number; ADL, Katz activities of daily living; IADL, Lawton instrumental activities of daily living.

Table 2. Health Outcomes of Older Traumatic Brain Injury Patients at 12 Months Post-Injury

Variable	*All Patients*	*Age 55–64 years*	*Age 65–74 years*	*Age 75–84 years*	p *Value*
MOS SF-36					
PCS subscale	38.2 (18.1)	39.5 (19.4)	39.5 (17.2)	35.3 (17.4)	0.01**,***
MCS subscale	49.3 (19.0)	48.1 (22.4)	51.7 (16.5)	48.2 (18.4)	0.005*,***
SF-6D	0.70 (0.27)	0.70 (0.29)	0.73 (0.25)	0.67 (0.26)	0.01***
No. of ADL/IADL difficulties	1.5 (3.0)	0.99 (2.85)	1.3 (2.7)	2.2 (3.2)	<0.0001**,***
Cognitive ability	68.2 (44.4)	70.1 (52.6)	71.1 (36.9)	62.8 (44.5)	0.04***
Depressive symptoms (%)	5.4%	7.5%	4.8%	2.6%	0.25

Significant *post-hoc* differences in age groups are denoted by *55–64 versus 65–74 years; **55–64 versus 75–84 years; ***65–74 versus 75–84 years.

Data are reported as mean (standard deviation) unless otherwise noted.

MOS SF-36, Medical Outcomes Survey Short Form-36; SF-6D, Short Form-36 health preference measure; PCS, physical component summary; MCS, mental component summary; ADL, Katz activities of daily living; IADL, Lawton instrumental activities of daily living.

the younger groups, and included increased numbers of rehospitalization/nursing home stays, and the use of home health services and unpaid care. The small but significant variance seen in rehospitalization/nursing home use may be related to differences in pre-injury heath status, as those in the oldest age category (75–84 years) were more likely to have difficulties with ADL/IADL and a higher Charlson index score pre-injury than those in the younger age groups. This poses special challenges, as injured older adults with significant comorbid medical conditions are at increased risk of complications and prolonged recovery (Grossman et al., 2002). Management may be further complicated by medications that complicate the injury, resuscitation, and recovery. With respect to drivers of cost among the groups, costs of index hospitalization were significantly lower in the youngest group in both models compared to the two older age categories, while post-index treatment costs were significantly higher. One of the primary drivers of increased treatment costs post-index hospitalization in the older age categories was rehospitalization. Older trauma patients experience an increased number of complications and higher long-term morbidity and mortality for any specific injury than their younger counterparts (Jacoby et al., 2006; McKevitt et al., 2003; Perdue et al., 1998). It is imperative that health care providers understand the complex clinical context in which traumatically-injured elders present, including both the implications of physiological changes associated with aging, and the complex interplay of significant comorbid medical conditions and medications that can complicate recovery and increase the risk of rehospitalization. As we were unable to determine if the reason for hospital readmission post-injury was either directly or indirectly related to injury, this will be important to identify in future studies, to both improve the quality of care and to reduce costs. Further, it will be important in future studies to determine if the cost variances seen in the present study are due to impact of early outcome, higher rates of post-injury disability and long-term sequelae of TBI in older age groups, current reimbursement policies, or some other as yet unidentified factors.

Table 3. Post-Index Hospitalization Health Care Utilization by Geriatric Traumatic Brain Injury Patients in the Year Post-Injury

Variable	*All subjects mean (SD)*	*Age 55–64 years*	*Age 65–74 years*	*Age 75–84 years*	p *Value*
Number of re-hospitalizations or nursing home stays	0.34 (1.36)	0.23 (1.31)	0.28 (1.16)	0.55 (1.55)	0.03**,***
Total number of times receiving physical or occupational therapy	2.7 (13.7)	2.7 (18.4)	3.6 (14.0)	1.7 (8.2)	0.24
Number of physician or other health professional visits	3.1 (7.4)	2.9 (9.6)	3.1 (5.5)	3.3 (7.3)	0.90
Number of physician visits related to injury	1.8 (6.3)	2.4 (10.2)	1.9 (4.2)	0.9 (2.8)	0.002**,***
Number of mental health professional visits	0.37 (2.98)	0.81 (5.46)	0.18 (1.47)	0.06 (0.65)	0.04**
Number of mental health professional visits related to injury	0 (0)	0 (0)	0 (0)	0 (0)	-
Receipt of paid home health care: Number of weeks receiving home health care	0.31 (1.61)	0.08 (0.94)	0.26 (1.41)	0.66 (2.04)	<0.0001**,***
Receipt of paid home health care: Number of times per week receiving home health care	0.36 (1.82)	0.11 (1.16)	0.22 (1.27)	0.85 (2.43)	0.0003**,***
Total number of times receiving home health	3.2 (20.7)	0.55 (6.91)	2.3 (16.2)	7.7 (28.9)	0.0004**,***
Receipt of care from friends or family: Number of days receiving unpaid assistance	2.3 (4.6)	2.2 (5.5)	2.1 (4.1)	2.5 (4.3)	0.54
Receipt of care from friends or family: Average number of hours on unpaid care/week	2.4 (8.5)	1.5 (6.6)	2.2 (7.6)	3.5 (10.1)	0.02**,***

Data are reported as mean (standard deviation).

Significant *post-hoc* differences between age groups are denoted by **55–64 versus 75–84 years; ***65–74 versus 75–84 years.

Table 4. Total and Service-Related Unadjusted Mean 1-Year Per-Patient Treatment Costs (Total and By Service) for Older Adult Traumatic Brain Injury Patients in 2005 (U.S. dollars)

Service category	*Age 55–64 years*	*Age 65–74 years*	*Age 75–84 years*	p *Value overall* (post-hoc *testing)*
Pre-index hospital care	909 (704, 1174)	854 (662, 1102)	918 (716, 1177)	0.84
Index hospitalization	31804 (24,355, 41,532)	25562 (19,546, 33,430)	15632 (11,978, 20,400)	0.0001 (<0.0001**, 0.004***)
Rehospitalization	7621 (4535, 12,805)	9096 (5357, 15,445)	13953 (8129, 23,950)	0.23
Inpatient rehabilitation	5203 (3122, 8671)	5427 (3230, 9118)	2264 (1339, 3829)	0.02 (0.02**, 0.01***)
Skilled nursing facility (nursing home) stays	1058 (587, 1905)	6471 (3530, 11,864)	13155 (7011, 24,685)	<0.0001 (<0.0001**, <0.0001*)
Post-index hospitalization outpatient care	5406 (4208, 6943)	9567 (7437, 12,306)	10377 (8081, 13,325)	<0.0001 (<0.0001**, 0.0001*)
Informal care from friends/family	8078 (6324, 10,319)	6590 (5119, 8483)	9421 (7245, 12,250)	0.14 (0.05***)
Total 1-year costs	77872 (64,475, 94,053)	76903 (63,192, 93,588)	72733 (59,147, 89,439)	0.88

Significant differences between age groups are denoted by *55–64 versus 65–74 years; **55–64 versus 75–84 years; ***65–74 versus 75–84 years.
95% Confidence intervals are presented in parentheses.

Similarly to prior findings from a study of older adults with TBI discharged from acute rehabilitative services (Graham et al., 2010), we found that the oldest group required significantly more home health care than younger groups (8 total visits compared to 1 or 2). In contrast, the oldest group received significantly fewer injury-related physician visits in the year post-injury, having on average a single physician visit related to the injury. Further, the number of overall physician visits in the year post-injury did not differ significantly across age groups, despite the lower overall level of pre-injury health in the oldest group. Two prior studies of service use in persons following TBI can provide additional context for our findings, although direct comparisons to the present report are difficult, given the differences in the ages of the samples (16–60 years of age), and the approach to defining physician visits (not defined based on relationship to injury). In the first 3 months post-discharge from a rehabilitation program, a subsample of adults participating in the Georgia Model Brain Injury System (GAMBIS) study reported seeing their physician about four times (Phillips et al., 2004). From 6–18 months post-injury, a sample of Australian adults with TBI received an average of 7.5 physician visits: 3.8 visits to their general practitioner and the remainder to specialists (Hodgkinson et al., 2000). Taken together with prior results from our group (Thompson et al., 2008,2010), these findings suggest that older adults with a TBI experienced a lack of coordinated care post-discharge, despite it being well established that they are at greater risk of developing complications, and experiencing disability and late mortality following traumatic injury. This strengthens our argument that aging-related health disparities may play a role in the poorer outcomes of older adults following injury.

Depression has been identified as a risk factor for TBI and is more prevalent following TBI (Bombardier et al., 2010). Further, depression following injury is associated with increased comorbidity (e.g., somatic complaints of pain or sleep disturbances), functional impairment, and poorer

Table 5. Total and Service-Related Adjusted Mean 1-Year Per-Patient Treatment Costs for Geriatric Traumatic Brain Injury Patients Adjusted for Demographic and Pre-Injury Health and Function in 2005 U.S. Dollars

Service category	*Age 55–64 years*	*Age 65–74 years*	*Age 75–84 years*	p *Value*
Pre-index hospital care	603 (430, 844)	560 (401, 782)	621 (438, 879)	0.75
Index hospitalization	28566 (20,296, 40,207)	25482 (18 151, 35,774)	18829 (13,171, 26,916)	0.04**
Rehospitalization	7527 (3762, 15,057)	9289 (4654, 18,541)	19079 (9133, 39,857)	0.03**,***
Inpatient rehabilitation	2153 (1125, 4119)	2261 (1184, 4316)	1458 (733, 2902)	0.34
Skilled nursing facility (nursing home) stays	1504 (662, 3418)	6250 (2754, 14,182)	8356 (3474, 20,101)	<0.0001*,**
Post-index hospitalization outpatient care	4258 (3037, 5970)	6392 (4568, 8944)	6792 (4760, 9690)	0.01*,**
Informal care from friends/family	8070 (5466, 11,915)	5655 (3832, 8345)	10,498 (6917, 15,934)	0.005*,***
Total 1-year costs	82,585 (62,066, 109,887)	80,939 (60,841, 107,676)	79,523 (58,529, 108,046)	0.97

Significant *post-hoc* differences between age groups are denoted by *55–64 versus 65–74 years; **55–64 versus 75–84 years; ***65–74 versus 75–84 years.
95% Confidence intervals are presented in parentheses.

quality of life (Zatzick et al., 2008). This can result in increased use of health care resources and costs of care. In the present report, the percentage of persons with depressive symptoms post-injury was lower than that reporting a physician-diagnosed history of depression pre-injury (14.5% versus 5.4%). However, a better reflection of depression at the time of injury is the percentage of the sample that was on medication for depression, 3.7%. At 12 months post-injury, those persons aged 55–64 had the highest rate (7.5%) of depressive symptoms. Further, this rate of depressive symptoms was more than 5% higher than the percentage of persons in the same age group with depression being treated at the time of injury. A similar increase in depressive symptoms was seen post-injury in persons aged 75–84 years. Despite this increase in depressive symptoms during the first year post-injury, there were no reported mental health visits related to injury. Moreover, the sample had on average less than one visit to a mental health care provider for any reason, with those aged 75–84 years having the lowest number of visits. Further work is needed to understand if the lack of mental health treatment is related to under-recognition of depression, lack of referral, lack of service availability, or patient preference. Additionally, given the relationship between depression and poorer post-injury outcomes, the use of evidence-based practice guidelines for the recognition and management of depression in the older adult is critical to minimize post-injury disability.

There are inherent limitations to the study due to the nature of the data available from the medical records and self-reports. Although the data were collected prospectively in the parent study, some cost-related information, including outpatient medication and durable medical equipment costs, were not available for analysis. Some of the data was obtained via self-report, particularly for those persons not covered by Medicare, which may underestimate the true utilization and cost of care received (MacKenzie et al., 2010). The parent NSCOT study excluded patients older than 84 years of age, thus there may be limited generalizability of the findings to adults aged > 85 years. Our results apply to the U.S. only, but additional sensitivity analyses could be performed to adjust for costs in other countries. We were unable to discern if differential outcomes seen in the present study (e.g., discharge disposition) was due to age biases built into the U.S. system or current reimbursement policies. Resource availability in different countries may vary (Aitken et al., 2010), and may further impact outcomes and thus should be considered when comparing findings internationally.

This study addresses a significant, understudied, and growing public health problem, the older adult with TBI. These findings provide a better understanding of the types and costs of health care services received by this population by more precisely quantifying the financial implications of this type of injury. The data presented here will be useful for future cost-effectiveness studies. Identifying variations in care that these patients are receiving and determining their costs versus benefits is an important next step in seeking potential areas for improvement. Utilization of services is different across the age sub-categories of geriatric TBI patients, and may provide information for both clinicians and researchers in identifying areas of potential intervention. Further, as health outcomes differed significantly across age categories, future researchers should recognize that older adults are a heterogeneous group, which has implications for both sampling and data analysis plans.

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Address correspondence to:
Hilaire J. Thompson, Ph.D., R.N., CNRN, FAAN
Biobehavioral Nursing and Health System
University of Washington
Box 357266
Seattle, WA 98195-7266

E-mail: hilairet@uw.edu