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Traumatic Brain Injury in Older Adults: Epidemiology, Outcomes, and Future Implications

Hilaire J. Thompson, PhD[*], **Wayne C. McCormick, MD, MPH**[†], and **Sarah H. Kagan, PhD**[‡]

**Biobehavioral Nursing and Health Systems, Division of Gerontology and Geriatric Medicine, University of Washington, Seattle, Washington*

†Department of Medicine, Division of Gerontology and Geriatric Medicine, University of Washington, Seattle, Washington

‡Department of Gerontologic Nursing, School of Nursing, University of Pennsylvania, Philadelphia, Pennsylvania

Abstract

Traumatic brain injury (TBI) is a significant problem in older adults. In persons aged 65 and older, TBI is responsible for more than 80,000 emergency department visits each year; three-quarters of these visits result in hospitalization as a result of the injury. Adults aged 75 and older have the highest rates of TBI-related hospitalization and death. Falls are the leading cause of TBI for older adults (51%), and motor vehicle traffic crashes are second (9%). Older age is known to negatively influence outcome after TBI. Although geriatric and neurotrauma investigators have identified the prognostic significance of preadmission functional ability, comorbidities, sex, and other factors such as cerebral perfusion pressure on recovery after illness or injury, these variables remain understudied in older adults with TBI. In the absence of good clinical data, predicting outcomes and providing care in the older adult population with TBI remains problematic. To address this significant public health issue, a refocusing of research efforts on this population is justified to prevent TBI in the older adult and to discern unique care requirements to facilitate best patient outcomes.

Keywords

traumatic brain injury; head injury; geriatric; trauma; injury; epidemiology; outcomes; functional status

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The Centers for Disease Control and Prevention has termed traumatic brain injury (TBI) the "silent epidemic,"[1] and within this silent epidemic, there is a seemingly silent population: older adults with TBI. Older age is a variable known to negatively influence outcome after TBI,[2–4] but analyses illuminating why this is the case, as well as information regarding age-appropriate care of elderly patients with TBI are sparse. Furthermore, despite the fact that geriatric and neurotrauma investigators have identified the prognostic significance of preadmission functional ability,[5] the presence of comorbidities,[6,7] sex,[8] and other factors such as cerebral perfusion pressure (CPP)[9] on recovery after illness or injury, these variables remain understudied in older adults with TBI. The relative neglect of these variables in neuroscience research may partially explain why predicting outcomes and providing care in the older adult population with TBI remains so problematic. The current "one size fits all" approach to

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Address correspondence to Hilaire J. Thompson, PhD, Box 357266, Seattle, WA 98195. E-mail: hilairet@u.washington.edu.
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management of adults with TBI often neglects the special issues of the older adult. This review addresses the epidemiology of TBI in older adults and factors affecting patient outcomes, focusing on the implications of the current state of knowledge and identifying areas for future research and clinical inquiry.

EPIDEMIOLOGY

In persons aged 65 and older, TBI is responsible for more than 80,000 emergency department visits each year, approximately three-quarters of which result in hospitalization.[10] The age-adjusted rate of hospitalization for nonfatal TBI in the general population is 60.6 per 100,000 population;[11] for adults aged 65 and older, this rate more than doubles—to 155.9.[12]

Falls are the leading cause of TBI for older adults (51%), and motor vehicle crashes (MVCs) (pedestrian or driver/passenger) are second (9%).[10] Assaults account for 1% of TBIs in older adults, and all other known causes account for 17%, although more than 21% of TBIs in older adults are from unknown causes.[10] In 2003, the aggregate charges for treating a principal diagnosis of TBI in patients aged 65 and older exceeded $2.2 billion.[13] If, as expected, the older population in the United States doubles from the current 35 million to 70 million by 2030,[14] the costs of caring for older adults with TBI in monetary and human terms will be staggering.

SEX, RACE, AND ETHNICITY

Risk factors for TBI in the general population include non-white ethnicity and male sex, although in a study of TBI data registries with race reporting from 13 states, 84% of TBI-related hospitalizations in older adults occurred in whites.[12] In subgroup analyses of age groups, this was true except in those aged 65 to 74, in which the highest rate of hospitalization occurred among American Indians/Native Alaskans, although this difference was not statistically significant. Male sex was associated with a higher incidence of TBI in older adults, but this differs from the elderly trauma population, in which women are most likely to be hospitalized after an injury.[15] Few studies have addressed these issues, and the reasons for the disparate findings in this population could be further elucidated.

Additionally, argument exists within the TBI field, in which female sex has been associated in animal[16] and clinical[8] studies with better outcomes after TBI; this improvement has been associated with the presence of estrogen and progesterone[17] (these levels change significantly following menopause) and their relation to maintenance of adequate cerebral perfusion.[18] However, because other experimental[19] and clinical[20] studies have refuted these findings, data are inconclusive at this point. Whether the effects of these hormones are neuroprotective, which could have implications for therapeutic intervention, remains unclear.

MECHANISMS OF INJURY

Falls

Approximately 8% of persons aged 65 and older visit the emergency department each year because of a fall-related injury.[21] About one-quarter of these visits result in inpatient admission.[22] Once they become inpatients, falls are also serious problems for older adults, because they average about 1.5 falls per bed per year while hospitalized.[21] Approximately 10% of falls in older people result in other injuries, such as TBI, and consequently, falls are the most common cause of TBI in older adults. In California from 1996 to 1999, 71% of fatal fall-related TBI occurred in adults aged 65 and older.[23] In 2002, the overall U.S. age-adjusted incidence rate of hospitalization from fall-related TBI was 29.6 per 100,000 population.[24] For adults aged 65 to 74, this rate was almost double (58.6/100,000 population), and in adults aged

75 and older, the rate was more than three times as high as that of any other age group (203.9/100,000).[24] Furthermore, a history of a single fall is a major risk factor for a subsequent fall,[25] increasing the risk of repetitive TBI, a clinically significant phenomenon that has not been formally investigated in older adults.

MVCs and Traffic

More than 154,000 older adults were injured in MVCs in the United States in 2002.[26] Older adults constituted only 14.4% of licensed drivers in 1999 but accounted for nearly 17% of drivers killed in MVCs. By 2020, demographers estimate that drivers aged 55 and older will constitute 30% of drivers.[27] By 2050, this proportion is expected to rise to nearly 40%. If unaddressed, the numbers of older adults killed or injured in MVCs will likely continue to increase.

Factors associated with older age are almost certainly a factor in MVCs as a mechanism of injury, although this has not been explored. Risk factors for greater mortality and injury in MVC involving drivers and pedestrians who are older include vision problems, slower reflexes, decreased bone density, comorbid conditions, frailty, cognitive impairment, and alcohol and medication use.[26–29] Injuries of older adult pedestrians are more severe than younger pedestrians involved in similar accidents.[28,30] Further work is required to assess the relationship between age, preinjury health status, comorbid health conditions, mechanism of injury, and outcomes.

Driving is an essential skill for maintaining independence and mobility for older adults, because automobiles are their primary means of transportation. Although research suggests that older adults self-regulate their driving behaviors as a consequence of functional limitations and difficult driving situations,[31,32] it is also essential that trained clinicians provide a thorough assessment of driving ability, particularly after an event such as TBI.

Attempted Suicide

The highest suicide rate for all age groups is found in adults aged 65 and older[33] and is the third leading cause of injury in adults aged 65 and older.[28] The most common method involves use of a firearm,[34] which places the older adult who survives an attempt at risk for penetrating TBI. Older adults living in urban settings choose jumping from a height as the method of suicide attempt, likely because of ease of access and high lethality;[35] thus, care providers should be aware of the high likelihood of polytrauma in these patients. In older adults, risk factors for suicide include being white and male; a history of depression, chronic pain, or illness; and social isolation.[28,33] Seventeen percent to 37% of older adults experience mild depressive symptoms.[36] In addition, 70% of older adults who completed suicide had seen their primary care provider within the previous month,[37] signifying that healthcare providers are not fully realizing a window of opportunity for intervention in this population. Because there is a high case-fatality rate associated with gunshot wounds and jumping from a height, primary prevention is central to the care of these patients.

CHRONIC HEALTH CONDITIONS IN OLDER ADULTS

In the United States, 48% of community-dwelling adults aged 65 and older have arthritis, 36% have hypertension, 27% have coronary disease, 10% have diabetes mellitus, and 6% have had a cerebrovascular accident.[38,39] One study[40] found that 73% of elderly TBI patients had a medical condition before injury, compared with 28% of younger adults. This significant increase in comorbidity may be important in primary and secondary prevention efforts. The relative risk of fall in older adults with diabetes mellitus is 1.97 compared with those without diabetes mellitus.[41] Because falls are the primary mechanism of injury in TBI in older adults, this population may be appropriate to target for primary prevention strategies, and this is an area for further study.

One study[12] used the 15-state Centers for Disease Control and Prevention TBI surveillance system database to examine the characteristics of hospitalized older adults with a TBI. Patients with fall-related TBI had more recorded comorbid conditions than those injured in MVCs.[12] Co-morbid conditions were similar between the two mechanisms of injury (hypertension, diabetes mellitus, cardiac arrhythmias, and fluid and electrolyte disorders), although the incidence of dementia, depression, and Parkinson's disease was higher in patients with fall-related TBI. Limitations of this study included inability to control for severity of initial injury, type of facility, and prior health status, factors that could influence outcome. In another study of patients with isolated closed head injury, the documented presence of a comorbid cardiac condition or coagulopathy significantly increased overall mortality.[42] Further work is needed in this area to better explicate the influence of comorbid conditions on the incidence of and outcomes after TBI in older adults.

Another study[43] found that 9% of older adult patients with TBI were taking warfarin preinjury, and this was associated with more severe TBI and a higher rate of mortality. The Practice Management Guidelines for Geriatric Trauma[7] note that the presence of comorbid conditions adversely affect outcome after an injury, but this effect becomes less pronounced with older age. Throughout the course of an intensive care unit stay, certain preexisting conditions place the elderly trauma patient at greater risk for secondary complications. These complications lengthened the hospital length of stay and increased mortality.[6,44] A higher number of medical comorbidities has also been associated with longer rehabilitation stays in older adults.[5] The development of subsequent complications has also been related to severity of injury. Nonetheless, older trauma patients with preexisting pulmonary disease were more than 1.6 times as likely to develop pneumonia as those without pulmonary disease.[44] One study[6] concluded that the type of preexisting condition, as well as injury severity and mechanism, must be taken into consideration when endeavoring to predict outcomes for older trauma patients.

Comorbid dementia or mild cognitive impairment, whether from Alzheimer's disease or other etiologies, is a risk factor for TBI[45,46] and for slower recovery from TBI.[47] Cognitive impairment is underdiagnosed in older patients.[48] Even when diagnosed by providers caring for older patients with TBI, it is often difficult to separate what part of cognitive impairment is due to preexisting dementia and what is due to TBI. Preexisting cognitive impairment confounds the diagnosis of TBI in such patients after trauma.

PHYSIOLOGICAL IMPLICATIONS OF AGING FOR TBI

Two major factors place older adults at risk for greater incidence of TBI. First, as one ages, the dura becomes more adherent to the skull. Second, as part of routine management of chronic conditions, more older adults receive aspirin and anticoagulant therapies. Thus, the mechanisms of injury most likely to be seen in elderly persons (e.g., fall, MVC) increase the risk for TBI. Other normal aging changes include cerebrovascular atherosclerosis and decreased free radical clearance.[49] The former could increase the risk of injury or cause a secondary insult, and the latter may increase oxidative damage after a TBI.[50] Moderate cerebral atrophy may be present in some older adults, which can cause occult findings to be present on head computed tomography (CT) despite an initial intact neurological examination.[49]

CPP MANAGEMENT

CPP is defined as mean arterial blood pressure minus intracranial pressure. Current guidelines recommend maintaining CPP at a minimum of 60 mmHg.[9] After severe TBI, cerebral autoregulation is altered. Little is known about the older brain, but a single study completed in healthy middle-aged and older adults (mean age 54 ± 8) found no change in dynamic cerebral autoregulation under normal conditions.[51] One study has evaluated changes in cerebral autoregulation after TBI in older adults, using transcranial Doppler technology, CPP, and intracranial pressure (ICP) to determine autoregulation and pressure reactivity indices in patients with TBI ranging in age from 16 to 87.[52] This study found that ICP decreased significantly with age, causing a significant rise in CPP. In addition, autoregulation and pressure reactivity indices were reported to decline significantly with increasing age, indicating decreased ability of the older brain to maintain cerebrovascular reactivity postinjury.[52] However, this study, like others examining older adult TBI, contained a disproportionate number of younger adults, which could limit the study's reliability. Also, although it offered an important first step, it provided only simple correlation of autoregulation indices with age and did not control for factors such as comorbid conditions.

Another gap is that no study has identified whether the current CPP guidelines are appropriate for management of the older adult with a TBI. In older adults, several age-specific factors contribute to making CPP management in TBI a complex issue that requires further investigation within this population. First, there is a high incidence of comorbid conditions, including hypertension and diabetes mellitus, which could affect the responsiveness and perfusion needs of the cerebral vasculature. Second, these persons may have been taking medications at the time of injury, which could affect the cerebrovascular response to injury. Future work needs to begin to focus on these issues and determine whether the current guidelines are adequate for older adults with TBI and in older adults with comorbid health conditions.

Lastly, because of the normal systemic changes attributable to aging, the ability of the cardiovascular system to respond to shock is impaired in older adults.[50] Further impeding this capacity may be medications taken by many elderly patients, such as beta blockers and antiplatelet agents. Elderly TBI patients with superimposed shock may appear stable. Guidelines for the management of elderly trauma patients recommend that optimal management goals for older adults after a trauma should be a cardiac index of 4 L/min or greater per m^2, oxygen consumption index of 170 mL/min per m^2, or both,[53] but these guidelines are based on only two studies,[54,55] one of which did not include patients with TBI and the other of which included only 17 patients with clinically significant TBI. More research is needed to discern the optimal hemodynamic management of older patients with TBI with shock, because it could affect cerebral perfusion. Although initial investigations examining the effects and outcome of hypovolemic shock in the setting of TBI have been conducted in animals[56,57] and humans,[58] these studies have not considered the consequences of aging.

TBI OUTCOMES IN OLDER ADULTS

Older age has long been recognized as an independent predictor of worse outcome from TBI.[2,12,52] The mechanism by which this occurs remains unknown. In a recent study of geriatric patients with a mild head injury (Glasgow Coma Scale (GCS) 13–15), 14% of patients had evidence of lesion on CT; 20% of these lesions required neurosurgical intervention.[59] Because research was unable to pinpoint useful clinical predictors of lesion formation, head CT scans are now recommended for all patients aged 65 and older presenting with neurological symptoms and signs or history of head trauma to aid TBI diagnosis.[59]

The financial and human costs of treating TBI in older adults are extensive. Mortality rates in adults with severe TBI aged 55 and older range from 30% to 80%,[60–63] significantly higher than those reported in younger patients. One study[64] reported greater mortality rates from TBI beginning at age 31, but the likelihood of death was maximal after age 71. In a meta-analysis evaluating the association between age and outcomes, another study[2] reported an optimal change point for mortality at age 60.

Mortality rates for older people with mild TBI are also substantially higher than for their younger counterparts.[65,66] Although a single study has reported that adults aged 60 and older who suffered mild TBI had significantly better functioning ($P<.05$) at 1 month postinjury on the Glasgow Outcome Scale (GOS) than younger persons with mild TBI, significance was not maintained when employment status was controlled for.[67] In studies that have examined disability after TBI, there is evidence to suggest that older adult TBI survivors have greater dependence than younger survivors using global outcome measures including the GOS[61,68] and the Functional Independence Measure.[65] In addition, older adults with TBI have longer lengths of stay[68] and are more likely to have delayed neurological decline.[62,69] As a result of the longer hospital stays, the cost of their care is significantly greater. These longer stays occur despite lower injury severity scores and higher mean GCS scores than those of their younger counterparts.[65] Once admitted to inpatient rehabilitation facilities, older patients with TBI require longer stays, resulting in greater costs.[3,61] Additional understanding of outcomes in older patients with TBI has been gleaned from the trauma literature. For any given injury, older trauma patients required more medical and subspecialty consultations and had more complications than their younger injured counterparts while hospitalized.[70] Limitations of currently available outcome studies in older adult patients with TBI include the focus on early outcome time points (e.g., discharge); given that older adults demonstrate slower rates of functional change after recovery from TBI,[3] this is an important consideration in future intervention and study design.

SUMMARY

There is a paucity of information available regarding TBI in older adults. Much of what is known is primary outcome data on mortality or GOS scores from subanalyses of larger studies. This is a significant gap in the literature; current care of older adults with TBI is guided solely by guidelines derived from previous work primarily done in younger adults. Although previous studies of adults with TBI have contributed to the care of this population, the failure to discern that the older TBI patient presents with different physiological and psychological needs frequently limits them. Likewise, animal model research has primarily focused on young adult male rodents. Recently, there has been an expansion of this work to include a number of investigators using juveniles and adult females in their studies, although the use of older animals remains scarce.[71] Thus the present translation of findings to the bedside from experimental work is limited in its ability to inform the care of geriatric TBI.

If viewed uncritically, the geriatric trauma literature can be misleading, contributing to mistaken conclusions about the effect of chronologic age on patient outcomes in TBI. For example, most data come from registries and care series prone to selection bias. Few researchers have used multiple or logistic regression, matching, or other statistical methods to control for the effects of important confounding variables, such as severity of initial injury, comorbidities, and baseline health status, when determining the effect of chronological age on outcomes after TBI. Furthermore, the substantial variation in mortality rates for older adults most likely reflects methodological and conceptual characteristics of the studies, such as definitions of older adult, which vary greatly, along with the sample sizes of the populations. Often studies examining age as a predictor of outcome have included limited numbers of older adults and have contained a disproportionate number of younger adults. Consequently, true mortality rates

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and definable outcomes in older adults with TBI are difficult to estimate. Factors other than older age, such as complications after TBI, may contribute to the increased morbidity and mortality rates seen. Most studies using age as a predictor of outcome have focused solely on mortality as an outcome (usually not the main finding or aim); thus there is little information available regarding functional outcomes in older adults. Further work is needed to determine the best measure of outcome(s) after TBI in the older adult, given the range of injury severity, participant burden of neuropsychological testing and multiple test batteries, and limitations of instruments originally designed for use in younger adults.

The need to study TBI in older adults is urgent, given the greater frequency with which older adults are experiencing TBI and being admitted to emergency departments and hospitals and the panoply of poor and costly outcomes, including high morbidity and mortality and the direct and indirect financial and human costs associated with this injury.

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