

# Traumatic Brain Injury in the Elderly: Burden, Risk Factors, and Prevention

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## ABSTRACT

Traumatic brain injury (TBI) is a major public health problem, affecting millions of people each year worldwide. Elderly patients are at particularly high risk after sustaining a TBI due to higher degrees of mortality and functional disability compared with younger patients. In addition, the causative mechanisms of TBI in the elderly are shifting from motor vehicle collisions to falls. In this article, we will review the risk factors and mechanisms that predispose elderly patients to sustain a TBI. We will conclude by using a “Haddon’s Matrix” approach to review current evidence-based prevention strategies directed at reducing the burden of TBI in the elderly.

## Key Words

Prevention, Traumatic brain injury

**T**raumatic brain injury (TBI) is a major public health problem, affecting more than 1.7 million patients annually in the United States alone,<sup>1</sup> and globally TBI is a major cause of death or permanent disability. The age of the population that TBI afflicts carries a bimodal distribution, mostly affecting the young (younger than 24 years old) and elderly (older than 65 years old).<sup>2</sup> Outcomes of TBI in the elderly, both in terms of mortality and function, are significantly worse in the

elderly population compared with younger patients. The incidence of TBI in the elderly is increasing at a time that we expect an explosive growth in the elderly population worldwide.

Although preventative public health measures, particularly in the realm of motor vehicle injury, have significantly reduced the incidence of TBI in the younger age group, the incidence of TBI in the elderly is on the rise, particularly due to an increasing burden of fall-induced TBI.<sup>3,4</sup> Recently, in a large population-based study, Ramanathan et al<sup>5</sup> showed that in the same time period (18 years) that the incidence of TBI has decreased in the young in Pennsylvania, it has more than doubled in the elderly. Thus, nurses caring for the geriatric population need to become increasingly aware of this growing problem. The primary aim of this review was to discuss the risk factors and mechanisms for TBI in the elderly. In addition, we will use a “Haddon’s Matrix” approach<sup>6</sup> to explore potential fall prevention strategies—Haddon’s Matrix allows the injury prevention community to better visualize risks and potential prevention measures surrounding an injury by focusing on the host, agent, and environment (Table 1).

## RISK FACTORS AND MECHANISMS FOR TBI IN THE ELDERLY

Although falls are the major contributor to TBI in the elderly population, several unique physiologic and clinical factors make the elderly more prone to a TBI with greater disability including greater frailty, chronic health conditions, polypharmacy, and poor strength and balance. The elderly often have a much higher degree of frailty (defined as decreased reserves in multiple organ systems)<sup>7</sup> compared with younger persons, which may account for greater disability after similar injuries sustained by younger persons. Thus, a head injury may be more severe and carry higher consequences in an elderly individual compared with younger individuals.

Elderly patients also often suffer from a high burden of chronic health conditions, which can often contribute to falls. One example of this is the increasing risk of arrhythmias with age, which can contribute to syncope-associated falls. To treat these conditions, often multiple medical therapies with poor side effect profiles can contribute to both a higher number of falls and fall-related injuries of greater severity. A prime example of this is the issue of

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**TABLE 1 A Haddon's Matrix Approach to Traumatic Brain Injury in the Elderly**

	Host/Agent	Environment
Pre-event	<ul style="list-style-type: none"><li>-Improved strength and balance</li><li>-Monitoring cognitive and health status</li><li>-Addressing polypharmacy</li></ul>	<ul style="list-style-type: none"><li>-Elimination of environmental hazards</li><li>-Bathroom safety interventions</li><li>-Repairing uneven surfaces and painting curbs</li><li>-Handrails</li><li>-Outside lighting</li></ul>
Event	<ul style="list-style-type: none"><li>-Antislip footwear</li><li>-Wearable sensor systems<sup>a</sup></li><li>-Helmets<sup>a</sup></li></ul>	<ul style="list-style-type: none"><li>-Impact absorbing floors</li><li>-Antislip floors</li></ul>
Postevent	<ul style="list-style-type: none"><li>-Hospital care</li><li>-Rehabilitation</li><li>-Appropriate disposition</li><li>-Social support</li></ul>	<ul style="list-style-type: none"><li>-Specific modifications based on local injury/mechanistic patterns</li></ul>

<sup>a</sup>Possible future interventions that have had less evaluation thus far.

anticoagulation for atrial fibrillation in the elderly. Atrial fibrillation carries a significant annual risk of ischemic stroke if anticoagulant therapy is not prescribed. However, the benefit of anticoagulant therapy may be outweighed by a greater degree of intracerebral bleeding and mortality in patients at a high risk of having a fall-induced TBI, even after relatively minor injuries.<sup>3</sup> Thus, it is imperative that providers carefully weigh the risk-benefit ratio when making decisions to prescribe anticoagulant therapy to patients who are at a high risk of falling. One approach is to carefully consider patient and treatment-specific factors using validated scoring systems such as the CHA(2)DS(2)-VASc and HAS-BLED scores.<sup>4</sup> In addition to anticoagulation, limiting the use of psychotropic medications, carefully monitoring response to antihypertensive and heart rate lowering medications, and eliminating unnecessary medications to avoid side effects and interactions<sup>8</sup> are other strategies that may help address pharmacologic factors that can contribute to an older adult falling. To this end, the Beers Criteria,<sup>9,10</sup> an expert consensus for identifying inappropriate medications in the elderly, may serve as a guide. Research employing the Beers Criteria has shown that more than 20% of older Americans receive at least 1 inappropriate drug.<sup>11</sup>

A recent body of evidence has demonstrated particular activities that contribute to falls and TBI in the elderly. In a large descriptive study performed in the Netherlands, Boye et al<sup>12</sup> examined the circumstances that led to a fall-induced TBI in elderly patients that presented to the emergency department; they found that the most common indoor activities performed at the time of their fall-induced TBI were walking on stairs and housekeeping

(51% and 17%, respectively) and the most common outdoor activities were walking and cycling (61% and 10%, respectively). In a study that prospectively collected video camera data to examine the exact mechanism of all falls (not only fall-induced TBI) at long-term care facilities, Robinovitch et al<sup>13</sup> showed that the most common cause of falling was incorrect weight shifting (41%), followed by a trip or stumble (21%). Taken together, the available data suggest that modifying the indoor and outdoor environment (to assist with stairs, as well as reduce trips/stumbles while walking), as well as increasing the strength and balance of elderly persons, may help contribute to decreasing the incidence of falls in the elderly.

There are several mechanisms that account for TBI in the elderly, spanning from firearms, motor vehicle collisions, and falls. Even though more elderly persons are driving, the majority of TBI in the elderly are attributable to falls, a large proportion which are from ground level.<sup>5</sup> In a study examining the epidemiology of severe TBI, Masson et al<sup>14</sup> showed that while a decrease in traffic collisions as the cause of TBI was observed, the proportion of severe TBI over the same time period attributable to falls in the elderly increased. As much public health preventative efforts have focused on reducing TBI through interventions aimed at reducing the burden of motor vehicle collisions, there may simply not be enough interventions specifically aimed at preventing fall-induced TBI.

## OUTCOMES OF TBI IN THE ELDERLY

In addition to the increasing incidence of TBI in the elderly patient population, this group unfortunately has

significantly worse outcomes compared with younger patients. This not only adds to the burden of functional disability after TBI, but also can dramatically increase health care costs due to the complexity of managing TBI in the elderly in the setting of multiple underlying chronic health conditions. In a large study examining 45 982 patients in the New York State Trauma Registry, Susman et al<sup>15</sup> showed that, at all levels of TBI severity, elderly patients (older than 65 years) had a significantly higher risk of in-hospital mortality (more than double) when compared with patients younger than 65 years. In the same study, elderly TBI patients also had higher rates of significant functional disability at discharge, as well as twice the rate of discharge to an extended care facility, when compared with their nonelderly counterparts.<sup>15</sup> Decisions regarding discharge disposition include issues surrounding social support and financing, which are complex problems that are of major concern in the elderly.<sup>16</sup> These outcomes confirm smaller studies that showed age to be an important predictor of outcome after TBIs.<sup>17,18</sup> More aggressive acute therapies in the elderly, including surgery,<sup>19</sup> have been suggested as a measure to improve outcomes in the elderly once they sustain a TBI. Taken as a whole, the available data suggest that TBI results in poorer survival and function in the elderly compared with younger patients. As with all injuries, the most comprehensive and cost-effective approach to reducing morbidity and mortality from TBI in the elderly is to focus on prevention.

## PREVENTION OF TBI IN THE ELDERLY

Although the increasing incidence of TBI in the elderly population has been postulated to involve a multifactorial interplay of host and environmental factors, the epidemiologic data clearly show that falls are the most common cause of TBI in the elderly. Thus, in addition to the clinical management strategies discussed above, efforts at fall prevention in the elderly—particularly targeted toward preventing fall-induced TBI—would likely represent the major public health intervention to decrease the burden of TBI in the elderly. Several gaps exist in the current literature regarding fall prevention as it applies to TBI, and this represents a major opportunity for clinical research aimed at effective prevention measures to reduce the burden of fall-induced TBI in the elderly.

### Host/Agent Factors

Several prevention measures aimed at the host and the agent aspects of fall preventions have been examined in both observational and randomized controlled studies. As mentioned above, 1 approach is to address clinical factors in the host, including appropriate medication management including patient education. Further approaches focused on the host include closely monitoring cognitive

and general health status and optimizing vision. Maintaining vitamin D levels in a normal range may contribute to improved strength and balance in elderly populations<sup>20</sup>; this may help target a key risk for sustaining a fall in the elderly patient population. Because of the increased risk for falling that is conferred by poor strength and balance, several intervention strategies have focused on improving strength and balance through group exercise programs, Tai Chi, and gait training.<sup>21,22</sup> Modification of footwear patterns by simply wearing any shoes indoors can significantly reduce the odds of an indoor fall.<sup>23</sup> In addition, although robust studies of this topic are not yet available, there is a small suggestion of benefit of antislip footwear to be effective on icy surfaces.<sup>24</sup> Finally, several TBI-specific interventions have been suggested, including the use of protective headgear for individuals at high risk for fall-induced TBI, as well as wearable sensor systems that provide an alert when individuals display high-risk movements. Unfortunately, because of the stigma that would likely be associated with these therapies, adherence to these interventions in community-dwelling elders would likely be low.

### Environmental Factors

Specific environmental modifications have been suggested as prevention measures for TBI in the elderly, as a result of the knowledge gained regarding the risk factors and circumstances surrounding falls. As tripping has been shown to occur at a fairly high frequency prior to a fall, the elimination of environmental hazards (both indoor and outdoor) may have promise in helping to reduce the rate of fall-induced TBI. Recent data from Stevens et al<sup>25</sup> showed that indoor falls are twice as likely to occur in bathrooms compared with living rooms; thus, bathroom safety interventions may help reduce the burden of indoor falls. Further elimination of outdoor environmental hazards could target sidewalks and curbs through repairing uneven surfaces and painting curbs. In addition, the modification of flooring to a more impact-absorbing or antislip function may help reduce the consequences of a fall or may prevent the fall from happening. The combination of indoor and outdoor modifications may also help decrease the rate of falls in the general population (although not specific to elderly) as recently demonstrated by Keall et al<sup>26</sup> in a cluster randomized controlled study; the authors were able to demonstrate a decrease in fall-induced injury from a program that included handrails for stairs, handrails in bathrooms, lighting outside, and slip-resistant outside surfacing. Modifications to the environment, while based on known risk factors, have not been subjected to rigorous analysis of effectiveness in fall-induced TBI prevention, although many indoor home-modifications do seem to be effective in smaller studies.<sup>24,27</sup>

## Multicomponent Intervention Bundles

As the studies evaluating the above prevention strategies are all very different in terms of their interventions, sample size, and outcomes, a recent Cochrane Database systematic review by Gillespie et al<sup>24</sup> attempted to synthesize the large quantity of heterogeneous data to find interventions that were effective in preventing fall by elderly individuals living in the community. The authors concluded that exercise programs (both group and home-based) were effective in reducing the rate and risk of fall; the results of vitamin D supplementation were less clear, but there was a suggestion that it may be effective in elderly patients with low vitamin D levels. The findings also confirmed the effectiveness of home safety interventions, improved vision (either with glasses or cataract surgery), pacemaker placement (in patients with carotid sinus hypersensitivity), and reduction of psychotropic medications.<sup>24</sup>

Although several individual fall prevention measures have been tested, the above results have led some to consider testing multiple interventions to further reduce fall risk. A “prevention bundle” of community-based interventions has been suggested, which includes a multicomponent focus on group exercise, fall education, and environmental modifications. Campbell and Robertson<sup>28</sup> conducted a meta-analysis examining the impact of community-based interventions (multicomponent focus on education, exercise, and environmental modification); they found these interventions to be effective, although suggested that single interventions may be as effective as multifactorial interventions. Furthermore, the Strategies to Reduce Injuries and Develop Confidence in Elders trial, funded by the National Institutes of Health and the Patient Centered Outcomes Research Institute, is a randomized clinical study that is currently underway to test the effectiveness of a comprehensive fall prevention strategy in the elderly.

## FUTURE DIRECTIONS

As explored above, several possible prevention measures at preventing falls in the elderly have been explored, with some having promising results when subjected to scientific investigation. Although the reduction of falls or fall-induced fractures might seem to be an appropriate surrogate end point, the rise in fall-induced TBI in the elderly despite the greater awareness of fall prevention speaks to the need for further research into prevention of fall-induced TBI. Specific implications surrounding future research include improved understanding of mechanisms and prevention measures for fall-induced TBI specifically. With the rising numbers of elderly persons in the United States and globally, research is desperately needed to fill these current gaps in our knowledge.

## CONCLUSION

Although we are expecting a dramatic increase in the elderly population globally, TBI continues to contribute to high morbidity, mortality, and health care costs in this vulnerable patient population. While we have gained insight into the modifiable risk factors for TBI in the elderly, particularly fall prevention, the best prevention strategy for fall-induced TBI in the elderly has yet to be elucidated, although some strategies do show promise. Clinicians should continue to focus on evidence-based therapies to maximize fall prevention including medication review, patient education, environmental assessment, and institution of strength and balance exercises. Researchers must continue to focus on discovering the most effective strategies to reduce the burden of fall-induced TBI.

### KEY POINTS

- Although the incidence of TBI is falling in younger age groups, TBI is on the rise in the elderly; as the size of the elderly population worldwide is growing, this represents a major public health problem.
- Falls continue to represent the major mechanism causing TBI in the elderly.
- Although we have gained insight into the modifiable risk factors for TBI in the elderly, particularly fall prevention, the best prevention strategy for fall-induced TBI in the elderly has yet to be elucidated.

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