Concussion and Older Adults

July 2022

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The British Columbia Injury Research and Prevention Unit (BCIRPU) was established by the Ministry of Health and the Minister's Injury Prevention Advisory Committee in August 1997. BCIRPU is housed within the Evidence to Innovation research theme at BC Children's Hospital (BCCH) and supported by the Provincial Health Services Authority (PHSA) and the University of British Columbia (UBC). BCIRPU's vision is to be a leader in the production and transfer of injury prevention knowledge and the integration of evidence-based injury prevention practices into the daily lives of those at risk, those who care for them, and those with a mandate for public health and safety in British Columbia. injuryresearch.bc.ca

The Concussion Awareness Training Tool (CATT) is a series of online educational modules and resources with the goal of standardizing concussion recognition, diagnosis, treatment, and management. Good concussion management may decrease the risk of brain damage and potentially reduce long-term health issues. Developed by Dr. Shelina Babul, Associate Director/Sports Injury Specialist with the BC Injury Research and Prevention Unit, BC Children's Hospital, and Clinical Professor, Department of Pediatrics, University of British Columbia, CATT is based upon the established principles of the Consensus Statement on Concussion in Sport and other evidence-based resources. The 2017 Berlin Concussion in Sport Group Consensus Statement builds on the principles outlined in previous concussion statements and aims to develop better understanding of sport-related concussion. cattonline.com

Authors: Mina Huang, Shelina Babul

For any questions regarding this report, contact:

BC Injury Research and Prevention Unit
F508 – 4480 Oak Street
Vancouver, BC V6H 3V4
Email: bcinjury@bcchr.ca
Phone: (604) 875-3776

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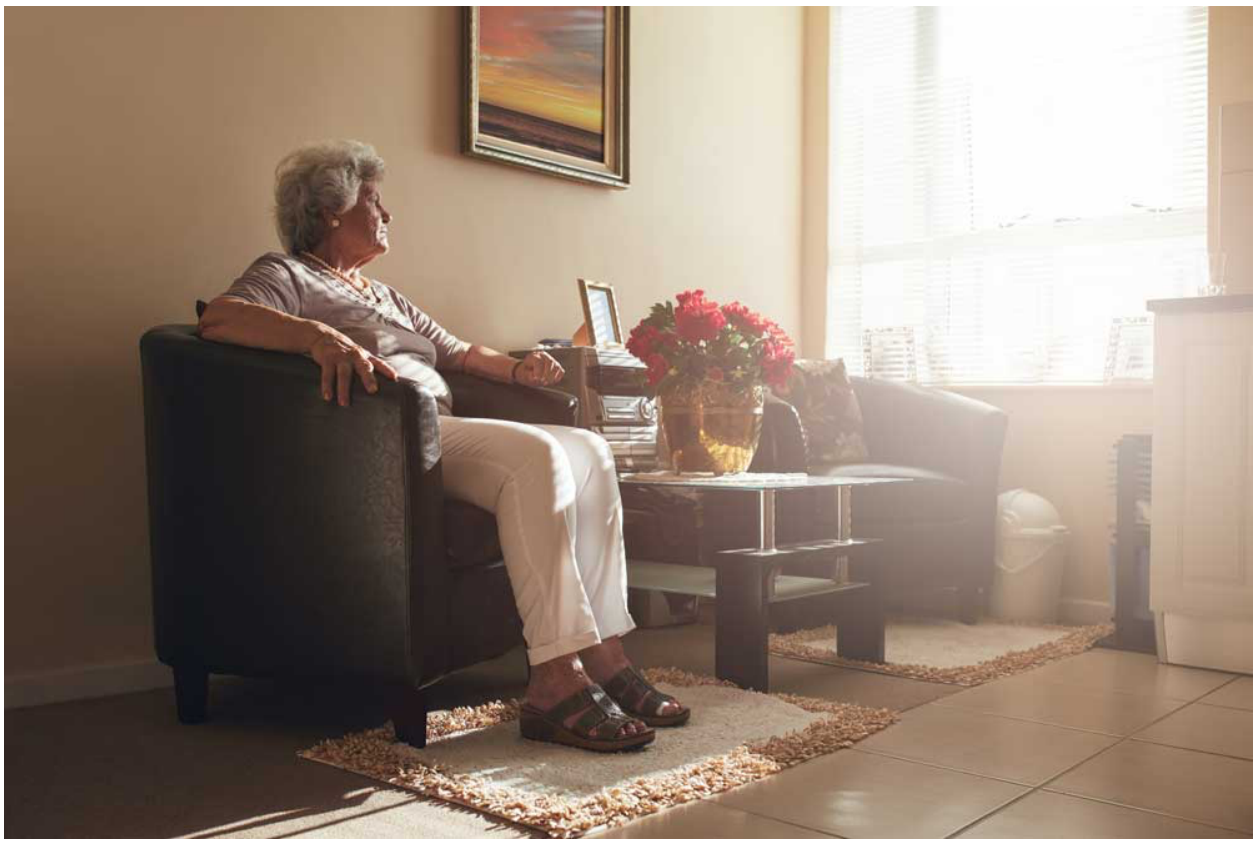
Key Highlights

- Older adults have unique risk factors that complicate presentation, diagnosis, and management of concussions
- Falls are the most common mechanism of injury for concussion in the elderly, unlike younger adults where the most common mechanism is sports injuries
- Pre-existing cognitive impairment, polypharmacy, and physical changes with aging increase the risk of falls
- Use of medications such as sedatives, psychotropics, and antithrombotics may increase the risk of concussions and concussion severity/complications
- Older adults may have increased risk of poor functional outcome post-concussion as well as increased risk of post-concussion syndrome and prolonged symptoms; however, there is some evidence to the contrary
- Older adults may present with less occurrences of loss of consciousness and higher GCS scores, which may decrease clinical suspicion for concussion
- Difficulty differentiating between delirium, pre-existing cognitive impairment, and cognitive effects resulting from concussion complicate concussion detection in seniors
- Elderly individuals are frequently excluded from clinical trials and studies, leading to a lack of understanding of concussions and seniors

Executive Summary

Concussions are the most common form of traumatic brain injury and are a particular concern for the elderly population as the presence of unique risk factors complicates the presentation, diagnosis, and management of concussions in older adults. Unlike younger adults, falls are the most common mechanism for concussion in the elderly, and factors such as pre-existing cognitive impairment, polypharmacy, and physical deterioration from age increase the risk of falls and therefore of concussions. The use of medications such as antithrombotic therapies, which are frequently prescribed to older adults, in addition to age-related physical factors also increase the risk of intracerebral hemorrhages after concussion. Along with an increased risk of sustaining concussions, older adults may also have increased risk of poor functional outcome and poorer recovery after a concussion than younger adults; however, there is some contrasting evidence regarding functional impairment post-concussion, and other studies suggest that older adults are able to make full recoveries post-injury. The presentation of concussions in older adults may differ from younger adults, often with less occurrences of loss of consciousness and higher GCS scores, which together with typically lower risk mechanisms of injury and lack of validated clinical tools, makes the detection and diagnosis of concussions in the elderly potentially challenging. Additionally, the cognitive impairment that may result from a concussion can be difficult to differentiate from delirium or pre-existing cognitive impairment, particularly when the individual's baseline is not known. Overall, there is a lack of research regarding the challenges of diagnosing and managing concussions in seniors as older adults are often excluded from studies and clinical trials. With the prevalence of concussions in the elderly and the potential impact on morbidity and mortality as well as general quality of life, more knowledge is required to guide the protocols and best practices around caring for seniors with concussions.



Introduction

Concussions are the most common form of traumatic brain injury (TBI), and result from forces impacting the head or body that cause injury to the brain.[1] While there is some ambiguity around the definition of concussions and mild traumatic brain injury (mTBI), the two terms are often used interchangeably.[2] Unlike for moderate or severe TBIs, the assessment of mTBIs is often particularly challenging due to the lack of objective tools that can be used for diagnosis, [2] and the assessment of mTBIs in older adults presents a particular challenge as polypharmacy, concurrent chronic health conditions, and the combination of physiological changes of age create unique presentations and also affect the severity and impact of mTBIs in the elderly.[3] This is of particular concern as mortality rates from TBIs in Canada are highest among adults aged 65 years or older.[2]

Risk Factors for Concussion Among Older Adults

Falls

While sports-related injuries are the most common mechanism for concussion among younger adults, older adults are more likely to have mechanisms related to falls and motor vehicle accidents.[4] In fact, about half of all TBIs[2] and about 85% of mTBIs in older adults resulted from ground-level falls, while 9.2% of mTBIs resulted from falls from other heights, and 5.8% resulted from other causes such as assault and motor vehicle accidents.[5,6] With the prevalence of mTBIs resulting from low falls, TBIs must be considered in older adults presenting after a fall regardless of the presence of any obvious head injury.[7]

With falls being the greatest risk factor for concussions among older adults, factors that increase risk of falls must also be examined. Mild cognitive impairment or dementia, having comorbid medical conditions, requiring assistance for ambulation, and polypharmacy (particularly of medications such as sedatives, psychotropics, or anticoagulants) are risk factors for falls in the elderly as well as subsequent admission for fall-related brain injury.[3] Additionally, older age is an independent risk factor for falls because of age-related deterioration in physical functions.

Physical Health Factors

Certain physical factors may contribute to fall-related TBIs in older adults, such as decreased neck strength and muscle activation in older age which can affect head control during a fall and result in more force transmitted to the brain on impact.[8] Older adults also have increased risk of traumatic intracranial hemorrhage due to structural changes to the brain with age such as brain atrophy, decreased adherence of the dura to the skull, and loss of elasticity of the bridging veins.[7]

Medications

Medication use is another risk factor for concussions among older adults. Older adults are commonly prescribed anticoagulant or antiplatelet therapies for various cardiovascular conditions, and some studies have shown that patients on these medications are at an increased risk of traumatic intracerebral hemorrhages and hematomas after falls from standing height.[9] There are differences in risk conferred by different anticoagulant medications, as the use of direct oral anticoagulants (DOACs) is associated with a reduced risk of traumatic intracerebral hemorrhages and overall adverse outcomes after an mTBI compared to Vitamin K antagonists, and DOACs confer a similar level of risk compared to antiplatelet medications.[9] Alternately, some evidence suggests that patients on aspirin alone or aspirin together with an anticoagulant were at a higher risk of intra-axial hemorrhage post-mTBI, while patients on anticoagulants alone were not at increased risk,[10] while other studies have shown that patients on antithrombotics had a similar rate of intracranial hemorrhages post-mTBI as patients not on anti-thrombotics.[11,12]

Impact of Concussions on Older Adults

Based on current research, there is some debate about the long-term impact of mTBIs on older adults, with some evidence suggesting that a single mTBI can affect the physical and cognitive functioning of seniors long-term[13] and that age over 75 years is an independent risk factor for adverse events in hospital post-mTBI[14], while other evidence suggests that elderly patients are able to fully recover from an mTBI with no long-lasting effects.

Functional Impairment

One study showed that older adults with a single mTBI within the previous 3-24 months and no history of neurological issues had decreased motor learning abilities compared to healthy controls when assessed on an implicit serial reaction time test, and that time elapsed since the injury did not have any effects on the deficits.[15] Other evidence also suggested that older adults had significantly worse overall functional performance one-year post-mTBI compared to younger adults, with specific concerns in mobility, ability to travel, and ability to maintain their home, and the deficits in mobility particularly impacted the social health of older adults. Additionally, though better pre-injury physical health was associated with better post-injury functional performance, better pre-injury mental health was associated with worse post-injury functional performance in seniors.[16]

However, there is also evidence that suggests that while older adults show greater functional impairment than younger adults at one-week post-injury, by 3-months post-injury older adults show similar levels of community integration to non-injured older adults, and that at 6-12 months post-injury, while older adults may show greater long-term disability than younger adults, that may or may not be related to other comorbidities. [17] Another study showed that older adults performed worse than community controls on prospective memory tasks at 3-months post-mTBI; however, there was no significant difference between the patients who had sustained an mTBI and patients who had sustained other orthopedic injuries, suggesting that a general predisposition to injury and the effects of a traumatic injury may be contributing factors to the cognitive difficulties seen in the mTBI patients.[18] Also, while patients older than 65 years old were more likely to have pre-existing functional impairment or dementia prior to their mTBI than younger patients, there was no significant difference in the total number of symptoms, in symptom severity, and in change in functional status at one-week post-injury, and younger patients were more likely to report post-traumatic amnesia as well as higher rates of symptoms than older patients.[19] A study that looked at several outcomes post-mTBI also showed that older adults had equivalent outcome trajectories post-mTBI compared to younger adults from 24-hours post-injury through to 6-months post injury in depressive symptoms, post-concussive symptoms, as well as functional recovery.[20]

Mental Health

Some evidence suggests that older adults don't experience elevated levels of psychological distress post-mTBI, and have fewer psychological symptoms than younger adults[17], such as anxiety.[21]

Post-Concussion Syndrome

In many studies, older adults are shown to be at higher risk of developing post-concussion syndrome[4] and are at higher risk of prolonged post-concussion syndrome, with symptoms lasting longer than 6-months after the injury.[22] There is also evidence that while the total number of symptoms do not differ

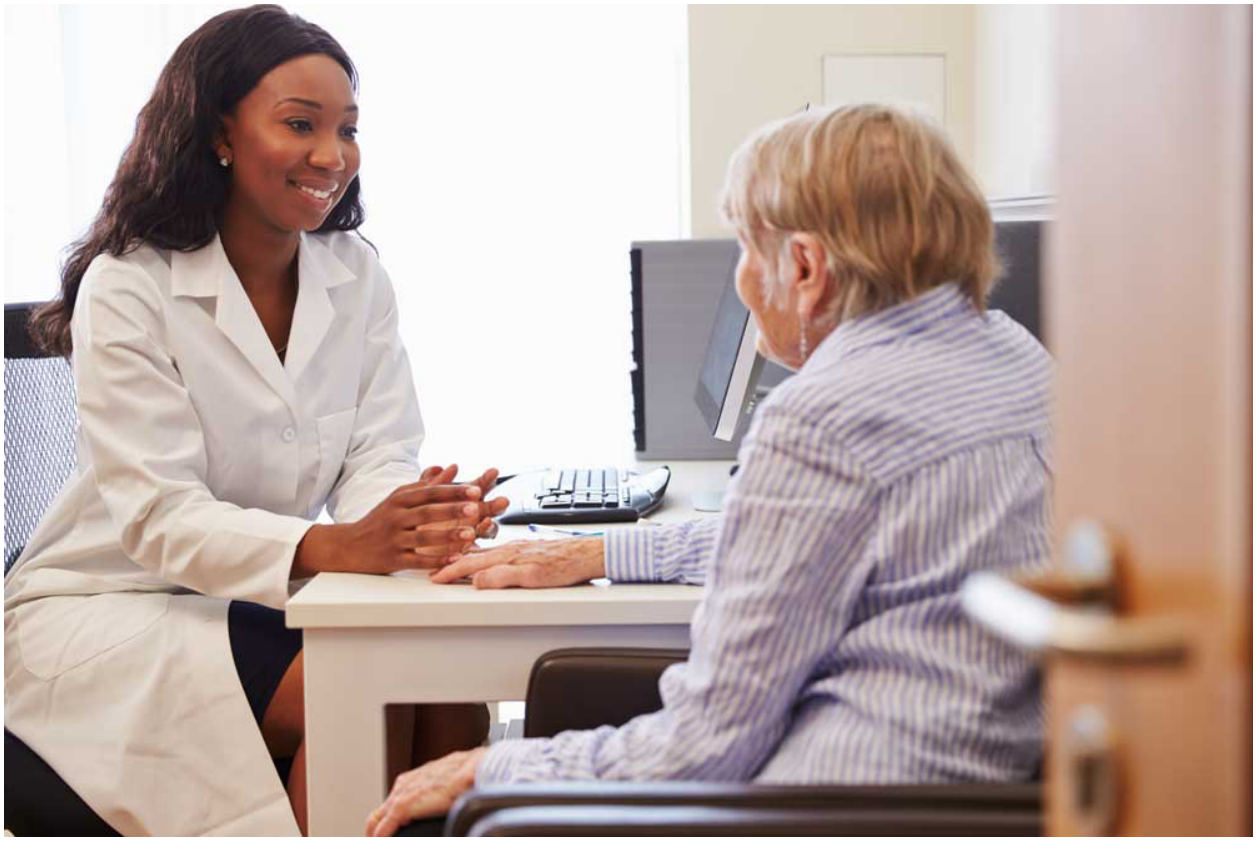
between older and younger patients in the first year post-mTBI, older adults experienced different symptoms and more severe symptoms. At one-week post-injury, older adults reported more issues with balance, fatigue, and dizziness, and at one-year post-mTBI, the most common symptoms in older adults were balance problems, fatigue, and discomfort with noise while younger adults reported more issues with memory, headaches, and anxiety. [23]

On the other hand, another study found that older patients reported less post-concussion symptoms than younger patients, and that age was not a significant predictor of post-concussion symptoms.[24]

Physical Brain Changes

While one study found that in a cohort of healthy aging adults, a lifetime history of self-reported mTBIs was not significantly associated with the rate of amyloid accumulation over several years[25], other evidence suggests that there is a higher risk of acute intracranial abnormalities following mTBI with older age[5], and in older patients, Alzheimer's dementia-like changes in functional brain activity can be seen on fMRI by 6-months post-injury.[26] Older patients also had increased white matter degradation in various areas of the brain, which may be due to the impact of the mTBI as well as the cumulative effect of other pathologies and their interactions with TBI.[27] Additionally, perturbations in brain physiology such as atypical activation patterns of visual processing in the left and right hemispheres during attention tasks are visible in elderly patients post-mTBI for months to years, suggesting that there may be adaptive functional reorganizations of sensory/perceptual responses post-mTBI.[28]

Conversely, there were more cerebral microbleeds found in older patients with mTBI compared to younger patients with mTBI; however, there was no significant difference in the number of cerebral microbleeds between older patients and older patients with mTBIs.[29] Increased age was also associated with a decreased risk of injury to the carotid and/or vertebral arteries with an mTBI, which is potentially related to the most common mechanism of injury in the elderly being falls, as falls have a decreased risk of cerebrovascular injury compared to other mechanisms of injury.[30]



Detection and Diagnosis of Concussions in Older Adults

Concussions in elderly patients present a particular challenge for detection and diagnosis as elderly patients often present with higher and more reassuring GCS scores and typically have minor mechanisms of injury compared to younger patients, which leads to inappropriate assumptions for stability, delayed treatment, and result in increased morbidity and mortality, as the GCS and injury severity scale are tools often used in emergency departments to prioritize patients.[31] With the increased risk of intracranial hemorrhages that may come with even mild TBIs in elderly patients, an adult over 65 years old is automatically considered high risk in the Canadian CT-Head rules, and head CTs are recommended to rule out acute conditions post-mTBI that may require surgical intervention.[7] On the other hand, the current age criterion of 65 years in the Canadian CT-Head rules has a sensitivity of 100% and a specificity of 0% for identifying clinically important brain injuries, and a study suggests that if the age criterion is raised to 75 years old, the sensitivity remains at 100% but the specificity will increase to 13.9%, though if the criterion is further raised to 80 or 85 years old, the sensitivity decreases to 90.6% and 75% respectively.[32]

In the search for a potential tool that could help screen for and detect mTBIs by looking for cognitive impairment, the MOCA, a test commonly used to assess for cognitive impairment in older adults, has been evaluated as a tool to assess for cognitive status post-mTBI, and differences in the visuospatial/executive and language sections were seen between patients with an mTBI and healthy controls. The severity of the mTBI was also significantly associated with a lower MOCA score, particularly for patients who had a lower GCS; however, many factors influenced an individual's MOCA score aside

from their head injury, such as age and education level, and hence those factors must be considered if the MOCA is to be used to screen for cognitive impairment post-mTBI.[33]

While many tools used to identify concussions are not validated in older adults and may not help to detect and diagnose concussions in that population, the presence of certain risk factors and symptomatology can help to increase suspicion or need for further investigations such as a head CT. For example, in patients on direct oral anticoagulants, major trauma or previous neurosurgery were associated with increased risk of intracranial hemorrhage, and post-mTBI factors such as temporary loss of consciousness, post-traumatic amnesia, a GCS <15, visible trauma above the clavicles, at least one episode of vomiting, seizure after the trauma, or signs of possible skull base fracture were also associated with increased risk of intracranial hemorrhage, with post-traumatic amnesia and loss of consciousness being the strongest predicting factors.[34]

With the potential ambiguity of clinical symptoms, research has been done into developing objective laboratory tests to aid in the detection of TBIs, such as serum S100B or GFAP and UCH-L1 levels; however, validating the use of these tests in older adults has also provided challenges, and none are currently available for routine clinical use.[7] In patients 65 years or older, serum GFAP and UCH-L1 showed a 100% sensitivity in detecting CT-positive intracranial injuries, which is equivalent to that of younger patients, but had a much lower specificity (13.1% for all patients >65 years old), and specificity dropped further as the age of the patient increased. Older patients also had higher serum GFAP and UCH-L1 levels in general, even among patients without CT-positive mTBIs.[35] The serum concentration of S100B also increases with age, and the threshold for suspicion of a TBI needs to be adjusted in older patients.[36]

There has also been research into risk factors and symptoms that may help determine prognosis, and some evidence suggests that higher baseline symptoms immediately after sustaining an mTBI as assessed on the Rivermead Post-Concussion Questionnaire is associated with increased overall disability and poorer self-perceived recovery at 6 months post-injury, which may help identify older adults with higher burdens of post-concussion symptoms that may require extra support with mobility and overall functioning after a concussion.[37] Another study found that older age at injury and increased symptoms following an mTBI were stronger indications of poorer self-perceived recovery 12-months post-injury, in contrast with earlier evidence that suggested that increased atypical symptoms (e.g. difficulty swallowing, difficulties with fine motor tasks, digestion problems) rather than typical symptoms were a strong indicator of poor recovery.[38]

Other factors that may be helpful to assess early after injury to help tailor the rehabilitation process include specific symptoms such as increased neck pain, irritability, and forgetfulness post-injury compared to pre-injury, as these symptoms are associated with incomplete recovery and long-term functional impairments after mTBI in elderly patients, though these are not the most prevalent symptoms (fatigue, headache, dizziness). Evidence also suggests that a certain selection of symptoms rather than a higher number of symptoms gives more information regarding prognosis.[39]

Challenges in Identifying Concussions in Older Adults

Some challenging factors in identifying concussions are particularly relevant to elderly patients, such as the difficulty in differentiating confusion and cognitive impairment due to an mTBI from delirium, pre-existing cognitive impairment, and sedative medication use, especially since the patient's baseline cognitive function is often unknown during the initial assessment.[1,7] There are also high rates of pre-existing functional impairment in older adults, often attributable to pre-existing or chronic medical conditions, that make the knowledge of the patient's baseline particularly important for assessment.[5] Additionally, older adults with mTBIs may present with normal mental and physical exams despite the presence of an intracranial lesion[6], and may also present with less loss of consciousness and/or post-traumatic amnesia than younger patients despite the presence of intracranial findings on CT.[35] In fact, with each 10-year increase in age, there was a 32% decrease noted in the odds of a documented loss of consciousness after a concussion, so a lack of documented loss of consciousness may not be a good indicator of lack of TBI in older patients. This has particular implications for determining the need for a CT scan, as the Canadian CT Head Rules excludes patients that did not have a documented loss of consciousness.[40]

Other behavioural factors such as potential hesitation in notifying others of a fall from fear of losing independence and less awareness of concussion symptoms in older adults due to less targeting of concussion awareness campaigns towards that demographic also contribute to difficulties in detecting concussions in elderly patients.[1]

Additionally, even though neurocognitive assessments following an mTBI are recommended, they are typically not part of routine evaluation protocols as there are few tools available, and even fewer that are validated or applicable to elderly patients, particularly considering the lack of knowledge of the patient's baseline that provides further challenges.[7]

Management of Concussion in Older Adults

Along with the limited research on the assessment and diagnosis of concussions in older adults, there is also limited research on the management of concussions in the elderly. Some evidence suggests that exercise may help to reduce persistent post-concussive symptoms and may also help lessen the severity of neuroinflammatory responses, which may help to lessen the impact of both aging and brain injury; however, much of the evidence currently comes from animal models and further investigation is required.[41] Therapies that target sleep may also have beneficial effects post-mTBI as many older adults have an increased risk of insomnia and other sleep disturbances up to 2-years post-TBI which may contribute to the cognitive impairments from the mTBI, on top of the changing sleep architecture that comes with increasing age.[41]

For immediate management of an older adult post-mTBI, evidence suggests that the rates of delayed intracranial hemorrhages after 24 hours post-mTBI are low, so elderly patients on anticoagulants should be observed for 12-24 hours and subsequently discharged and followed from home if their CT and INR results are normal.[3]

There is also evidence that suggests that the use of a statin during the 90 days post-mTBI is associated with a reduced risk of dementia, and that same reduction in risk is not seen in patients who had sustained an ankle sprain and subsequently treated with a statin.[42]

Overall, older patients appear to benefit from targeted and timely rehabilitation to mitigate the effects of the loss of independence and cognitive decline that often occur post-mTBI in the elderly.[3]

Further Research Required/Gaps in the Literature

Despite the increasing prevalence of concussions in elderly individuals, there is a lack of research regarding the challenges of diagnosing and managing concussions in seniors as older adults are often excluded from studies and clinical trials[43]. Considering the impact of these injuries on morbidity and mortality as well as general quality of life, more knowledge is required to guide the protocols and best practices around caring for seniors with concussions.

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Associated With Decreased Odds of Documented Loss of Consciousness After a Concussion. *Front Neurol*. 2020;11(January):1-9. doi:10.3389/fneur.2020.00039

41. Markovic SJ, Fitzgerald M, Peiffer JJ, et al. The impact of exercise, sleep, and diet on neurocognitive recovery from mild traumatic brain injury in older adults: A narrative review. *Ageing Res Rev*. 2021;68(March):101322. doi:10.1016/j.arr.2021.101322

42. Redelmeier DA, Manzoor F, Thiruchelvam D. Association Between Statin Use and Risk of Dementia After a Concussion. *JAMA Neurol*. 2019;76(8):887-896. doi:10.1001/jamaneurol.2019.1148

43. Peters ME, Gardner RC. Traumatic brain injury in older adults: do we need a different approach? *Concussion*. 2018;3(3):CNC56. doi:10.2217/cnc-2018-0001

Appendix 1: List of papers and findings included in document

See Excel file

Appendix 2: List of papers in each included systematic review

Green – appears independently in the report document as well
Orange – appears in more than one systematic review

Hume 2021 - *Systematic Review and Meta-analysis of Outcome after Mild Traumatic Brain Injury in Older People*

- Abdulle 2018 - *Early predictors for long-term functional outcome after mild traumatic brain injury in frail elderly patients. Journal of Head Trauma Rehabilitation*
- Abdulle 2020 - *The role of mood, post-traumatic stress, post-concussive symptoms and coping on outcome after MTBI in elderly patients*
- Van der Naalt 2017 - *Early predictors of outcome after mild traumatic brain injury (UPFRONT): an observational cohort study.*
- Deb 1998 - *Neuropsychiatric sequelae one year after a minor head injury.*
- Hu 2017 - *Is age associated with the severity of post-mild traumatic brain injury symptoms?*
- Karr 2019 - *Age, symptoms, and functional outcome after mild traumatic brain injury. – 2020?*
- Kinsella 2014 - *Mild traumatic brain injury in older adults: Early cognitive outcome.*
- Kristman 2016 - *Prognostic markers for poor recovery after mild traumatic brain injury in older adults: A pilot cohort study.*
- Asselstine 2020 - *The Rivermead Post-Concussion Questionnaire score is associated with disability and self-reported recovery six months after mild traumatic brain injury in older adults.*
- Mosenthal 2004 - *The effect of age on functional outcome in mild traumatic brain injury: 6-Month report of a prospective multicenter trial.*
- Rapoport 2001 - *Age and functioning after mild traumatic brain injury: The acute picture.*
- Rapoport 2003 - *Age and major depression after mild traumatic brain injury.*
- Richey 2020 - *Age differences in outcome after mild traumatic brain injury: results from the HeadSMART study.*
- Peters 2018 - *Traumatic brain injury in older adults: do we need a different approach?*

Marrone 2020 - *Management of Mild Brain Trauma in the Elderly: Literature Review.*

- Adams SD, Holcomb JB. Geriatric trauma. *Curr Opin Crit Care.* 2015;21:520–526. doi:10.1097/MCC.0000000000000246.
- Batey M 2018 - *Direct oral anticoagulants do not worsen traumatic brain injury after low-level falls in the elderly.*
- Beynon C 2015 - *Rivaroxaban and intracranial haemorrhage after mild traumatic brain injury: A dangerous combination?*
- Bouras T 2007 - *Head injury mortality in a geriatric population: differentiating an "edge" age group with better potential for benefit than older poor-prognosis patients.*
- Brousseau AA 2017 - *Comparison of functional outcomes in elderly who have sustained a minor trauma with or without head injury: A prospective multicenter cohort study.*
- Callaway DW, Wolfe R. Geriatric trauma. *Emerg Med Clin North Am.* 2007;25:837–60.
- Campiglio L 2017 - *Mild brain injury and anticoagulants: Less is enough.*

- Cetty L 2017 - *Prevalence and correlates of traumatic brain injury (TBI) in older adults: Results from the Well-being of the Singapore Elderly (WiSE) study*
- Cheng PL 2014 - *Higher mortality rates among the elderly with mild traumatic brain injury: A nationwide cohort study.*
- Chenoweth JA 2018 - *Incidence of delayed intracranial hemorrhage in older patients after blunt head trauma*
- Clement CM 2006 - *Clinical features of head injury patients presenting with a glasgow coma scale score of 15 and who require neurosurgical intervention.*
- Cohen DB 2006 - *Traumatic brain injury in anticoagulated patients*.
- Collins CE 2014 - *Effect of preinjury warfarin use on outcomes after head trauma in medicare beneficiaries.*
- Cruise CM 2006 - *Rehabilitation outcomes in the older adult*
- de Guise E 2015 - *Traumatic brain injury in the elderly: A level 1 trauma centre study.*
- Depreitere B 2012 - *Traumatic brain injury in the elderly: A significant phenomenon.*
- Evans D 2015 - *Elderly fall patients triaged to the trauma bay: Age, injury patterns, and mortality risk.*
- Filer W 2015 - *Falls and traumatic brain injury among older adults.*
- Flaada JT 2007 - *Relative risk of mortality after traumatic brain injury: A population-based study of the role of age and injury severity.*
- Flanagan SR 2005 -*The impact of age on traumatic brain injury*
- Franko J 2006 - *Advanced age and preinjury warfarin anticoagulation increase the risk of mortality after head trauma.*
- Fu WW 2017 - *Predictors of falls and mortality among elderly adults with traumatic brain injury: A nationwide, population-based study*
- Gaastra B 2016 - *The ageing population is neglected in research studies of traumatic brain injury.*
- Gangavati AS 2009 - *Prevalence and characteristics of traumatic intracranial hemorrhage in elderly fallers presenting to the emergency department without focal findings: Intracranial hemorrhage in elderly fallers.*
- Grandhi R 2015 - *Preinjury warfarin, but not antiplatelet medications, increases mortality in elderly traumatic brain injury patients.*
- Haring RS 2015 - *Traumatic brain injury in the elderly: Morbidity and mortality trends and risk factors.*
- Haydel M 2012 - *Management of mild traumatic brain injury in the emergency department.*
- Haydel MJ 2003 - *Indications for computed tomography in patients with minor head injury.*
- Helmes E 2011 - *Incremental contribution of reported previous head injury to the prediction of diagnosis and cognitive functioning in older adults.*
- Herou E 2015 - *Acute traumatic brain injury: Mortality in the elderly*
- Howard JL, 2nd 2009 - *Preinjury warfarin worsens outcome in elderly patients who fall from standing.*
- Ivascu FA 2005 - *Rapid warfarin reversal in anticoagulated patients with traumatic intracranial hemorrhage reduces hemorrhage progression and mortality*
- Jagoda AS 2008 - *Clinical policy: Neuroimaging and decisionmaking in adult mild traumatic brain injury in the acute setting*.
- Jiang JY. 2013 - *Head trauma in China*
- Julien J 2017 - *Antithrombotic agents intake prior to injury does not affect outcome after a traumatic brain injury in hospitalized elderly patients*

- Kaen A 2010 - *The value of sequential computed tomography scanning in anticoagulated patients suffering from minor head injury.*
- Karibe H 2017 - *Clinical characteristics and outcome in elderly patients with traumatic brain injury: For establishment of management strategy.*
- Kim DY 2012 - *Venous thromboembolism in the elderly: The result of comorbid conditions or a consequence of injury?*
- Krishnamoorthy V 2015 - *Traumatic brain injury in the elderly: Burden, risk factors, and prevention.*
- Kristman VL 2014 - *Methodological issues and research recommendations for prognosis after mild traumatic brain injury: Results of the international collaboration on mild traumatic brain injury prognosis*
- Lavoie A 2004 - *Preinjury warfarin use among elderly patients with closed head injuries in a trauma center.*
- LeBlanc J 2006 - *Comparison of functional outcome following acute care in young, middle-aged and elderly patients with traumatic brain injury.*
- Levin HS 1997 - *Depression as a secondary condition following mild and moderate traumatic brain injury.*
- Li J 2001 - *Mild head injury, anticoagulants, and risk of intracranial injury.*
- Mahler B 2015 - *Unprovoked seizures after traumatic brain injury: A population-based case-control study.*
- Mann N 2018 - *Delayed intracranial hemorrhage in elderly anticoagulated patients sustaining a minor fall.*
- Menditto VG 2012 - *Management of minor head injury in patients receiving oral anticoagulant therapy: A prospective study of a 24-hour observation protocol.*
- Menzel JC. 2008 - *Depression in the elderly after traumatic brain injury: A systematic review.*
- Miller J 2015 - *Delayed intracranial hemorrhage in the anticoagulated patient: A systematic review.*
- Moore MM 2012 - *Impact of age and anticoagulation: Need for neurosurgical intervention in trauma patients with mild traumatic brain injury*
- Mosenthal AC 2004 - *The effect of age on functional outcome in mild traumatic brain injury: 6-month report of a prospective multicenter trial*
- Nishijima DK 2012 - *Immediate and delayed traumatic intracranial hemorrhage in patients with head trauma and preinjury warfarin or clopidogrel use.*
- Parra MW 2013 - *Dabigatran bleed risk with closed head injuries: Are we prepared?*
- Pedersen AR 2015 - *The effect of age on rehabilitation outcome after traumatic brain injury assessed by the functional independence measure (FIM)*
- Pieracci FM 2007 - *Degree of anticoagulation, but not warfarin use itself, predicts adverse outcomes after traumatic brain injury in elderly trauma patients.*
- Riccardi A 2013 - *Minor head injury in the elderly at very low risk: A retrospective study of 6 years in an Emergency Department (ED)*
- Riccardi A 2017 - *Intracranial complications after minor head injury (MHI) in patients taking Vitamin K antagonists (VKA) or direct oral anticoagulants (DOACs)*
- Salottolo K 2014 - *The effect of age on Glasgow coma scale score in patients with traumatic brain injury.*
- Scantling D 2017 - *The role of delayed head CT in evaluation of elderly blunt head trauma victims taking antithrombotic therapy.*
- Shimoda K 2014 - *Outcome and surgical management for geriatric traumatic brain injury: Analysis of 888 cases registered in the Japan Neurotrauma Data Bank*

- Stapert S 2006 - *Neurocognitive fitness in the sub-acute stage after mild TBI: the effect of age.*
- Stocchetti N 2012 - *Traumatic brain injury in an aging population*
- Susman M 2002 - *Traumatic brain injury in the elderly: Increased mortality and worse functional outcome at discharge despite lower injury severity.*
- Swap C. 2016 - *Risk of delayed intracerebral hemorrhage in anticoagulated patients after minor head trauma: The role of repeat cranial computed tomography.*
- Teo DB 2018 - *Characteristics of fall-related traumatic brain injury in older adults*
- Tseng JH 2014 - *Risk factors for chronic subdural hematoma after a minor head injury in the elderly: A population-based study*
- Van den Brand CL 2018 - *Traumatic brain injury in the Netherlands, trends in emergency department visits, hospitalization and mortality between 1998 and 2012.*
- Werman HA 2011 - *Development of statewide geriatric patients trauma triage criteria.*

Santing 2022 - *Mild traumatic brain injury in elderly patients receiving direct oral anticoagulants: A systematic review and meta-analysis*

- Beynon 2015 - *Intracranial haemorrhage in patients treated with direct oral anticoagulants.*
- Billings 2020 - *Newer and better? Comparing direct oral anticoagulants to warfarin in patients with traumatic intracranial hemorrhage.*
- Cipriano 2021 - *Predictors of post-traumatic complication of mild brain injury in anticoagulated patients: DOACs are safer than VKAs.*
- Cocca 2019 - *Delayed intracranial hemorrhage in anticoagulated geriatric patients after ground level falls.*
- Cohan I 2020 - *Repeat computed tomography head scan is not indicated in trauma patients taking novel anticoagulation: a multicenter study.*
- Cohan II 2020 - *Routine repeat head CT does not change management in trauma patients on novel anticoagulants.*
- Feeney 2016 - *Compared to warfarin, direct oral anticoagulants are associated with lower mortality in patients with blunt traumatic intracranial hemorrhage: a TQIP study*
- Galliazzo 2019 - *Intracranial bleeding risk after minor traumatic brain injury in patients on antithrombotic drugs*
- Jentzsch 2018 - *Is rivaroxaban associated with higher morbidity and mortality in patients with traumatic head injuries? A retrospective cohort study comparing rivaroxaban, no anticoagulation, and phenprocoumon*
- Parra 2013 - *Dabigatran bleed risk with closed head injuries: are we prepared?*
- Pozzessere 2015 - *Dabigatran use does not increase intracranial hemorrhage in traumatic geriatric falls when compared with warfarin.*
- Prexl 2018 - *The impact of direct oral anticoagulants in traumatic brain injury patients greater than 60-years-old.*
- Savioli 2020 - *Rates of intracranial hemorrhage in mild head trauma patients presenting to emergency department and their management: a comparison of direct oral anticoagulant drugs with vitamin K antagonists*
- Shin 2020 - *Comparison of traumatic intracranial hemorrhage expansion and outcomes among patients on direct oral anticoagulants versus vitamin K antagonists.*

- Spinola 2019 - *Hemorrhagic risk and intracranial complications in patients with minor head injury (MHI) taking different oral anticoagulants*
- Turcato 2019 - *Direct oral anticoagulant treatment and mild traumatic brain injury: risk of early and delayed bleeding and the severity of injuries compared with vitamin K antagonists.*