ERABI EVIDENCE-BASED REVIEW of moderate to severe ACQUIRED BRAIN INJURY

TRAUMATIC BRAIN INJURY AND OLDER AGE

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Conflict of Interest

In the context of ERABI development, the term “conflict of interest” (COI) refers to situations in which an author or ERABI staff member’s financial, professional, intellectual, personal, organizational or other relationships may compromise their ability to independently conduct this evidence-based review. No limiting conflicts were identified.

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Greetings from Dr. Robert Teasell,

Professor and Chair-Chief of Physical Medicine and Rehabilitation

The Collaboration of Rehabilitation Research Evidence (CORRE) team is delighted to present the Evidence-Based Review of moderate to severe Acquired Brain Injury (ERABI) *Traumatic Brain Injury (TBI) and Older Age* Through collaboration of researchers, clinicians, administrators, and funding agencies, ERABI provides an up-to-date review of the current evidence in brain injury rehabilitation. ERABI synthesizes the research literature into a utilizable format, laying the foundation for effective knowledge transfer to improve healthcare programs and services.

We offer our heartfelt thanks to the many stakeholders who are able to make our vision a reality. Firstly, we would like to thank the Ontario Neurotrauma Foundation, which recognizes ERABI's capacity to lead in the field of brain injury evidence-based reviews and is committed to funding it. We would also like to thank the co-chairs of ERABI, Dr. Mark Bayley (University of Toronto) and Dr. Shawn Marshall (University of Ottawa) for their invaluable expertise and stewardship of this review. Special thanks to the authors for generously providing their time, knowledge and perspectives to deliver a rigorous and robust review that will guide research, education and practice for a variety of healthcare professionals. We couldn't have done it without you! Together, we are building a culture of evidence-based practice that benefits everyone.

We invite you to share this evidence-based review with your colleagues, patient advisors that are partnering within organizations, and with the government agencies with which you work. We have much to learn from one another. Together, we must ensure that patients with brain injuries receive the best possible care every time they require rehabilitative care – making them the real winners of this great effort!

Robert Teasell, MD FRCPC

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Preface

About the Authors

ERABI is internationally recognized and led by an interprofessional team of clinicians and researchers with the goal of improving patient outcomes through research evidence. Each ERABI module is developed through the collaboration of many healthcare professionals and researchers.

Cecilia Flores-Sandoval, PhD, is the research coordinator of the Evidence-Based Review of Acquired Brain Injury (ERABI). She completed a master's and a doctoral degree in Health and Rehabilitation Sciences, field of Health and Aging at Western University. Her research interests include aging and rehabilitation, patient engagement and transitional care for older adults.

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Purpose

The Evidence-Based Review of Acquired Brain Injury (ERABI) is a systematic review of the rehabilitation literature of moderate to severe acquired brain injuries (ABI). It is an annually updated, freely accessible online resource that provides level of evidence statements regarding the strength of various rehabilitation interventions based on research studies. The ERABI is a collaboration of researchers from London, Toronto and Ottawa. Our mission is to improve outcomes and efficiencies of the rehabilitation system through research synthesis, and by providing the foundational research evidence for guideline development, knowledge translation, and education initiatives to maximize the real-world applications of rehabilitation research evidence.

Key Concepts

Acquired Brain Injury

For the purposes of this evidence-based review, we used the definition of ABI employed by the Toronto Acquired Brain Injury Network (2005). ABI is defined as damage to the brain that occurs after birth and is not related to congenital disorders, developmental disabilities, or processes that progressively damage the brain. ABI is an umbrella term that encompasses traumatic and non-traumatic etiologies.

TABLE 1 | Defining Acquired Brain Injury

Included in ABI definition	Excluded from ABI definition
Traumatic Causes • Motor vehicle accidents • Falls • Assaults • Gunshot wounds • Sport Injuries **Non-traumatic Causes** • Tumours (benign/meningioma only) • Anoxia • Subarachnoid hemorrhage (non-focal) • Meningitis • Encephalitis/encephalopathy (viral, bacterial, drug, hepatic) • Subdural Hematoma	**Vascular and Pathological Incidents** • Intracerebral hemorrhage (focal) • Cerebrovascular accident (i.e., stroke) • Vascular accidents • Malignant/metastatic tumours **Congenital and Developmental Problems** • Cerebral Palsy • Autism • Developmental delay • Down's syndrome • Spina bifida with hydrocephalus **Progressive Processes** • Alzheimer's disease • Pick's disease • Dementia • Amyotrophic Lateral Sclerosis • Multiple Sclerosis • Parkinson's disease • Huntington's disease

Given that 'ABI' can have multiple definitions, studies with an 'ABI' population can be equally heterogeneous in terms of the sample composition. Such studies may include any combination of persons with TBI, diffuse cerebrovascular events (i.e., subarachnoid hemorrhage) or diffuse infectious disorders (i.e., encephalitis or meningitis). The vast majority of individuals with ABI have a traumatic etiology; therefore, much of the brain injury literature is specific to TBI. The terms ABI and TBI have been used intentionally throughout ERABI to provide more information about populations where relevant.

Moderate to Severe Brain Injury

ABI severity is usually classified according to the level of altered consciousness experienced by the patient following injury (Table 2). The use of level of consciousness as a measurement arose because the primary outcome to understand the severity of an injury is the Glasgow Coma Scale. Consciousness levels following ABI can range from transient disorientation to deep coma. Patients are classified as having a mild, moderate or severe ABI according to their level of consciousness at the time of initial assessment. Various measures of altered consciousness are used in practice to determine injury severity. Common measures include the Glasgow Coma Scale (GCS), the duration of loss of consciousness (LOC), and the duration of post-traumatic amnesia (PTA). Another factor used to distinguish moderate and severe brain injury is evidence of intracranial injury on conventional brain imaging techniques which distinguish severity of injury from a mild or concussion related brain injury.

TABLE 2 | Defining Severity of Traumatic Brain Injury, adapted from Veterans Affairs Taskforce (2008) and Campbell (2000)

Criteria	Mild	Moderate	Severe	Very Severe
Initial GCS	13-15	9-12	3-8	Not defined
Duration LOC	< 15minutes*	<6 hours	6-48 hours	>48 hours
Duration PTA	< 1hour*	1-24 hours	1-7 days	>7 days
	*This is the upper limit for mild traumatic brain injury; the lower limit is any alteration in mental status (dazed, confused, etc.).			

Methods

An extensive literature search using multiple databases (CINAHL, PubMed/MEDLINE, Scopus, EMBASE, and PsycINFO) was conducted for articles published in the English language between 1980–April 2022 that evaluate the effectiveness of any intervention/treatment related to ABI. The references from key review articles, meta-analyses, and systematic reviews were reviewed to ensure no articles had been overlooked. For certain modules that lacked research evidence the gray literature, as well as additional databases, were searched to ensure the topic was covered as comprehensively as possible.

Specific subject headings related to ABI were used as the search terms for each database. The search was broadened by using each specific database's subject headings, this allowed for all other terms in the database's subject heading hierarchy related to ABI to also be included. The consistent search terms used were "head injur*", "brain injur*", and "traumatic brain injur*". Additional keywords were used specific to each module. A medical staff librarian was consulted to ensure the searches were as comprehensive as possible.

Every effort was made to identify all relevant articles that evaluated rehabilitation interventions/ treatments, with no restrictions as to the stage of recovery or the outcome assessed. For each module, the individual database searches were pooled, and all duplicate references were removed. Each article title/abstract was then reviewed; titles that appeared to involve ABI and a treatment/intervention were selected. The remaining articles were reviewed in full.

Studies meeting the following criteria were included: (1) published in the English language, (2) at least 50% of the study population included participants with TBI (as defined in Table 1) or the study independently reported on a subset of participants with TBI, (3) at least three participants, (4) ≥50% participants had a moderate to severe traumatic brain injury (as defined in Table 2), and (5) involved the evaluation of a treatment/intervention with a measurable outcome. Both prospective and retrospective studies were considered. Articles that did not meet our definition of TBI were excluded.

Interpretation of the Evidence

The levels of evidence (Table 3) used to summarize the findings are based on the levels of evidence developed by Sackett et al. (2000). The levels proposed by Sackett et al. (2000) have been modified; specifically, the original ten categories have been reduced to five levels. Level 1 evidence pertains to high quality randomized controlled trials (RCTs) (Physiotherapy Evidence Database, PEDro ≥6) and has been divided into two subcategories, level 1a and level 1b, based on whether there was one, or more than one, RCT supporting the evidence statement.

The evidence statements made in evidence-based reviews are based on the treatment of groups rather than individuals. There are times when the evidence will not apply to a specific case; however, the majority of patients should be managed according to the evidence. Ultimately, the healthcare professional providing care should determine whether an intervention is appropriate and the intensity with which it should be provided, based on their individual patient's needs. Furthermore, readers are asked to interpret the findings of studies with caution as evidence can be misinterpreted. The most common scenario occurs when results of a trial are generalized to a wider group than the evidence allows. Evidence is a tool, and as such, the interpretation and implementation of it must always be done with the known limitations in mind.

TABLE 3 | Levels of Evidence

Level	Research Design	Description
1A	Randomized Controlled Trial (RCT)	More than one RCT with PEDro score ≥6. Includes within subject comparisons, with randomized conditions and crossover designs
1B	RCT	One RCT with PEDro ≥6
2	RCT	One RCT with PEDro <6

	Prospective Controlled Trial (PCT)	Prospective controlled trial (not randomized)
	Cohort	Prospective longitudinal study using at least two similar groups with one exposed to a particular condition
3	Case Control	A retrospective study comparing conditions including historical controls
4	Pre-Post Trial	A prospective trial with a baseline measure, intervention, and a post-test using a single group of subjects
	Post-test	A prospective intervention study using a post intervention measure only (no pre-test or baseline measurement) with one or more groups
	Case Series	A retrospective study usually collecting variables from a chart review
5	Observational study	Using cross sectional analysis to interpret relations
	Clinical Consensus	Expert opinion without explicit critical appraisal, or based on physiology, biomechanics or "first principles"
	Case Reports	Pre-post or case series involving one subject

Strength of the Evidence

The methodological quality of each randomized controlled trial (RCT) was assessed using the Physiotherapy Evidence Database (PEDro) rating scale developed by the Centre for Evidence-Based Physiotherapy in Australia (Moseley et al., 2002). The PEDro is an 11-item scale; a point is awarded for ten satisfied criterion yielding a score out of ten. The first criterion relates to external validity, with the remaining ten items relating to the internal validity of the clinical trial. The first criterion, eligibility criteria, is not included in the final score. A higher score is representative of a study with higher methodological quality.

TRAUMATIC BRAIN INJURY

AND OLDER AGE

Summary of the Evidence

Outcome	Key Point Level of Evidence
Mortality	
In-Hospital Mortality	In-hospital mortality rates tend to be higher in older adults when compared to younger populations. - *There is level 2 evidence that older adults present with higher in-hospital mortality rates than their younger counterparts.*
Intensive Care Mortality	Mortality rates in the ICU tend to be higher for older individuals. - *There is level 2 evidence that older adults admitted to intensive care present with higher mortality rates than younger patients.*
Surgical Mortality	Surgical mortality tends to be higher in individuals aged 55 years and older, when compared to younger individuals. Surgery in older adults need to be considered on a case-by-case basis. - *There is level 2 evidence that surgical mortality is higher among older adults, compared to younger adults, with mortality rates after decompressive craniectomy being greater than 30%.*
Post-Hospital Discharge Mortality	Post-hospital discharge mortality tends to be higher in older when compared to younger adults, with higher rates in those 75 years and older. - *There is level 2 evidence that mortality post-hospital discharge can be higher in older adults compared to their younger counterparts, with higher rates observed in those over 75 years old.*
Comorbidities and Complications	
Comorbidities and Complications	The presence of comorbidities and medical complications may increase mortality rates in older adults who have sustained a TBI. - *There is level 2 evidence that having multiple comorbid conditions is associated with increased mortality rates and unfavorable outcomes in older adults who have sustained a TBI.*
Acute Care	
Acute Care Management	Injury severity may be underestimated in older adults during triage in emergency care, thus contributing to increased mortality. - *There is level 2 evidence that older adults may be triaged to a lower priority in emergency departments and offered conservative rather than aggressive acute care treatment.*

Neurosurgical Care	While there are associated risks, older adults may still benefit from neurosurgery; particularly those with higher GCS scores (>8). - *There is level 2 evidence that more aggressive treatments, including neurosurgical intervention, may increase survival in older age adults with moderate to severe TBI; particularly patients with GCS >8.*
Hospitalization	
Hospitalization and Readmission	Older adults with moderate to severe TBI may experience high rates of hospitalization and readmission. - *There is level 2 evidence that older adults with TBI may be at a higher risk of hospitalization and readmission than younger adults.*
Discharge Disposition	
Discharge Disposition	Older adults with moderate to severe TBI may be more likely to be discharged to long-term care, skilled nursing facilities and palliative care than younger individuals, and may be more likely to require support when discharged home. - *There is level 2 evidence that older adults with TBI may be more likely to be discharged to non-home facilities than younger individuals, and those discharge home may require additional supports.* -
Recovery Outcomes	
Glasgow Outcome Scale	Older adults may experience poor recovery outcomes and low Glasgow Outcome Scale (GOS) scores when compared to their younger counterparts; however, GOS scores may improve post discharge. - *There is level 2 evidence that while GOS scores at discharge are lower in older adults than in younger adults, scores may improve post-discharge, in association with functional gains in cognition, balance and activities of daily living.*
Functional Independence Measure	While the recovery of older adults with TBI may be slower than younger adults, they may attain functional gains as measured by the Functional Independence Measure (FIM) from admission to discharge with similar recovery of function. - *There is level 2 evidence that older adults may attain similar functional gains when compared to younger cohorts, as assessed by the FIM.*
Rehabilitation	
Community Reintegration	Life satisfaction post moderate to severe TBI may increase with age; however, social participation, quality of life and independence may decline, particularly in those 80 years and older.

	- *There is level 2 evidence (Anke et al., 2015; Niemeier et al., 2021) that, while life satisfaction may increase with age, social participation declines, with the lowest scores shown in individuals 85 years of age and older.* - *There is level 2 evidence (Gross & Amsler, 2018) that older and younger adults may present with comparable quality of life outcomes up to age 80, with a slight decrease thereafter.* - *There is level 2 evidence (Testa et al., 2005) that older individuals with moderate to severe TBI may be less likely to be independent, when compared to younger individuals.*
Cognition	Cognitive scores many be lower in older individuals with moderate to severe TBI, when compared with younger adults. - *There is level 2 evidence (Cifu et al., 1996; Davis & Acton 1988) that older adults with moderate to severe TBI may present with lower cognitive scores that their younger counterparts.*
Mental Health	Persons reporting higher life satisfaction post-severe TBI were more likely to report lower depression and anxiety scores and be over 65 years old than those with lower life satisfaction; however, further research is needed. - *There is level 2 evidence (Anke et al., 2015) that individuals who are satisfied with life after severe TBI are more likely to be 65 years and older and more likely to report lower depression and anxiety scores, when compared to those unsatisfied with life. However, further research is needed.*

Introduction

The term "aging" is often used in the literature to describe how adults progress developmentally to an older state of being. From the biological perspective, aging involves a gradual decline in function that causes progressive deterioration and eventually leads to tissue dysfunction (McHugh & Gil, 2018). Aging is considered an irreversible physiological process that occurs in living organisms over time; in humans, the aging process is complex and individualized, and encompasses biological, psychological and social factors (Dziechciaż & Filip, 2014).

Traumatic brain injury (TBI) is a leading cause of death in older adults and often has devastating long-term effects (Frankel et al., 2006). Not only can TBI have consequences for the individual, but also for the health care system, as well as for families and caregivers. TBI in older age has been considered a 'silent epidemic' and a major public health concern, with rising numbers of emergency department visits and hospitalizations and deaths, particularly for fall-related injuries (Peters & Gardner, 2018). Older adults with TBI are more likely to present with comorbidities, and experience higher mortality, demonstrate slower rates of recovery and worse functional outcomes, when compared to younger adults (Waltzman et al., 2022). In the United States, according to the Centers for Disease Control and Prevention, the highest rates of TBI-related deaths occur among individuals aged 75 years and older (Taylor et al., 2017). Traumatic injury in older adults accounted for $25 billion in healthcare expenditures and that was more than 15 years ago (Agency for Healthcare Research and Quality, 2005). Although seniors only account for 10% of all TBIs, they account for 50% of TBI-related deaths (Livingston et al., 2005).

According to the Canadian Institute for Health Information (CIHI) (2006), during the fiscal year 2003-2004, 29% of all head injury hospitalizations in Canada were adults aged 60 years or older, which represented 4,902 hospital admissions among older adults alone; these statistics are particularly alarming, given that the older adult population made up only 12% of the total Canadian population in 2004. In addition, many head injuries go unreported when individuals initially present to their family physician's office or other outpatient healthcare settings and remain undiagnosed in individuals that do not seek medical assistance. In 2004, 1,368 individuals who had experienced a head injury died in the hospital as a result of their injuries, the majority of which were adults over the age of 60 years (59%). The number of deaths reported in hospitals does not include individuals who died at the scene of an accident or before arriving to the hospital; therefore, it is estimated that the number of fatalities is significantly higher than what is reported (Canadian Institute for Health Information CIHI, 2006).

This module provides an overview of the incidence and etiology of TBI in older adults over the age of 65 years old. To be inclusive of research conducted in countries where the life expectancy is lower, and to provide a more comprehensive picture of research on TBI and older adults, we included studies that considered the older age threshold to be at 50 years and older, as well as studies comparing older adults to other age groups. Studies addressing the population of interest are presented throughout the module and are discussed critically to present relevant outcomes. It should be noted that older adults as a population have been underrepresented in clinical trials (Florisson et al., 2021; Habicht et al., 2008). Therefore, a larger proportion of studies on this population have retrospective or longitudinal cohort designs.

Mechanism of Injury

According to the Canadian Institute for Health Information (2006), the predominant mode of injury for older Canadian adults in 2004 was unintentional falls, representing 76% of all head injury admissions in this population; further, 82% of all injury related admissions of Canadian older adults were the result of a fall (Canadian Institute of Health Information, 2019). When examining the relationship of mortality and mechanisms of injury in older adults, half of TBI-related deaths occur in those over the age of 65 (Stein et al., 2018). Falls to the ground, either from a standing position or a height may be result from deterioration of physical functioning (e.g., visual, auditory difficulties), balance issues, orthostatic hypotension, dehydration, weakened muscle strength and cognitive decline (e.g., dementia), as well as the use of medications (Karibe et al., 2017). Other risk factors for falls among older adults include environmental factors (e.g., uneven surfaces), inappropriate footwear, lack or improper use of an assistive device (e.g., cane), and difficulties using public transit (Phelan & Ritchey, 2018). Falls in old age may also be caused by attempted suicide, particularly among individuals with history of depression and chronic pain, as well as those who experience social isolation (Thompson et al., 2006).

In 2004, the second and third leading causes of head injury in older Canadian adults were motor vehicle collisions and assaults at 17% and 1.1%, respectively (Canadian Institute for Health Information, 2006). From 2007 to 2013, TBI-death rates due to falls had increased among older adults, and those 75 years and over had the highest rates of fall-related emergency department visits, hospitalizations and deaths (Taylor et al., 2017). The rates due to motor vehicle collisions are particularly worrisome given that older adults drive considerably less than younger adults. The rate of death resulting from motor vehicle collisions in those 65 years and older was 13.2 per 100,000, yet for those aged 45 to 64 years, the rate was only 8.2 per 100,000 (Ramage-Morin, 2008). Risk factors for motor vehicle collisions involving older adults include frailty, presence of cognitive impaitment, medication use, slow reflexes and vision problems (Thompson et al., 2006).

Incidence by Age and Sex

Male sex has been associated with a higher incidence of TBI. According to the Centers for Disease Control and Prevention, males with TBI had higher age-adjusted rates of emergency department visits and hospitalizations, compared to females; in addition, males had higher rates of being struck by or against an object, and injury related to a motor-vehicle collision, intentional self-harm, and assault (Taylor et al., 2017). This overrepresentation of males is observed across the age spectrum in TBI (Zygun et al., 2005). However, some studies conducted in the United States have shown that sex differences regarding TBI incidence disappear over the age of 65 years (Tieves et al., 2005). In a study of 1610 individuals in Spain over the age of 65 years who had experienced falls, females were disproportionately affected by falls (Martín-Sánchez et al., 2018). This is consistent with reports from the Canadian Institute for Health

Information (CIHI) which states that 63% of hospitalizations among older adults were female, with 4 out of 5 hospitalizations occurring as a result of a fall. At the time of the fall, the majority of females were identified as independent or partially independent; in addition, among those who experienced a fall, 18% also experienced a TBI, while 6.4% experienced loss of consciousness (Martín-Sánchez et al., 2018).

Mortality

It is widely accepted that individuals over 65 years of age experience worse outcomes post TBI than those who are younger (Krishnamoorthy et al., 2015). Mortality rates have been reported to be higher for older adults with severe TBI, particularly during the first 6 months post-injury (McIntyre et al., 2013). According to several studies, individuals who are 56 years of age and older experience different outcomes following major trauma compared to those who are younger; further, older individuals have higher mortality rates (up to 62%) at discharge from acute care regardless of TBI severity (Bouras et al., 2007; Kuhne et al., 2005; Mosenthal et al., 2002; Spaniolas et al., 2010; Susman et al., 2002). While the literature generally lumps all individuals over 65 years together, some studies have shown that there may be key differences in recovery and outcomes even within this group. For instance, Bouras et al. (2007) examined mortality rates of older adults with mild to severe TBI who were stratified by age (14-64, 65-74, and ≥75 years of age) and found that mortality rates were significantly different between the two oldest age brackets (29%, and 47.4% respectively).

In-Hospital Mortality

Older adults with TBI have higher rates of emergency department visits, hospitalizations and in-hospital mortality than their younger counterparts (Taylor et al., 2017). Older adults who present with delayed deterioration or 'talk and deteriorate', also experience a progressive decrease in survival within the first 48 hours post-injury (Karibe et al., 2017). In addition, older patients with TBI often have multiple medical comorbidities that can make the clinical management of this population challenging (Krishnamoorthy et al., 2015). Other factors that may impact mortality include pre-injury functional and health status, the use of aggressive treatment protocols, and the presence of 'do not resuscitate' orders (Mattingly & Roth, 2022). Table 3 presents findings related to in-hospital mortality among older adults with moderate to severe TBI.

TABLE 3 | In-Hospital Mortality in Older Adults Post TBI

Author Year Country Study Design Sample Size	Injury Severity	Age and Sex	In-Hospital Mortality Rate
van Wessem & Leenen (2022) Netherlands Cohort N=391	AIS Head=3	*Age < 25yr* (n=76). Male=74%, Female=26% *Age 25-49yr* (n=142). Male=74%, Female=26% *Age 50-69yr* (n=101). Male=73%, Female=27% *Age ≥70yr* (n=72). Male=51%, Female=49%	*< 25yr*=16% *25-49yrs*=10% *50-69yr*=14% *≥70yr*=47%
Fröhlich et al., (2020)	Severe TBI=69%	*Level 1 Trauma Center* Mean Age=76.7yr	*≥65yr*=26.3%

Author Year Country Study Design Sample Size	Injury Severity	Age and Sex	In-Hospital Mortality Rate
Germany Cohort N=124,641	Mild-Moderate=31%	Male=60.9%, Female=39.1% *Level 2 Trauma Center* Mean Age=77.4yr Male=57.4%, Female=42.6% *Level 3 Trauma Center* Mean Age=78.3yr Male=52.8%, Female=47.2%	
Ruge et al. (2020) Sweden Cohort N=306	Mean AIS=4.3	*<60yr* (n=87) Mean Age=46yr Male=71.3%, Female=28.7% *>60yr* (n=219) Mean Age=81yr Male=56.6%, Female=45.4%	Overall mortality=48% *>60yr* (Mortality by AIS) AIS 3=15.2% ASI 4=20.0% AIS 5=27.7%
Chico-Fernandez et al., (2020) Spain Cohort N=465	Mean ISS=20.5 AIS Head=2.67	Mean Age=83.4yr Male=60.43%, Female=39.56%	19.2%
Maiden et al. (2020) Australia Cohort N=540	GCS 3-4=271 GCS 5-6=102 GCS 7-8=167	Age ≥65yr Male=55.37%, Female=44.62%	93%
Skaansar et al., (2020) Norway Cohort N=1,571	GCS=10-12.5	*Age 15-24yr* (n=179). Male=74.9%, *Age 25-34yr* (n=168). Male=79.8% *Age 35-44yr* (n=153). Male=81.7% *Age 45-54yr* (n=197). Male=73.6% *Age 55-64yr* (n=258). Male=75.6% *Age 65-74yr* (n=297). Male=67.7% *Age 75-84yr* (n=197). Male=56.9% *Age ≥85yr* (n=122). Male=37.7%	*15-54yr*=6% *55-64yr*=11% *65-74yr*=11% *75-84yr*=23% *≥85yr*=24%
Ostermann et al., (2018) Austria Case Series N=292	*Survived* AIS Head=3.39 *Died* AIS Head=4.39	*Survived* (n=215) Mean Age=79.8yr Male=89, Female=126 *Died* (n=77) Mean Age=83.4yr Male=37, Female=40	26.4%
Enumah et al., (2018) USA Case Series N=50,342	AIS ≥3 ISS 16-24=54.6%	Male=58.4%, Female=41.6% *Age 65-74*=31.4% *Age 75-84%*=43.1% *Age ≥85*=25.5%	61.2%

Author Year Country Study Design Sample Size	Injury Severity	Age and Sex	In-Hospital Mortality Rate
Dhillon et al. (2018) USA Cohort N=288	Mean GCS=12.8 AIS head/neck=3.9 ISS=19.2	Mean Age=80.2yr Male=50.69%, Female=49.30%	17.7%
Lilley et al. (2018) USA Cohort N=34,691	Severe TBI	Median Age=79yr (IQR 72-84) Male=59.1%, Female=40.8%	49%
Fu et al., (2017) Canada Cohort N=43,823	Median ICISS=0.8	Male=51.88%, Female=48.11% *Survivors* Median Age =79yr (IQR 12) *Non-Survivors* Median Age =83yr (IQR 12)	16%
Salottolo et al., (2017) USA Cohort N=481	GCS=3 AIS≥4=71%	*Vehicular-related Injuries* (n=285) Male=76.5%, Female=23.4% Age ≥65yr=40% *Fall-related Injuries* (n=1960) Male=68.4%, Female=31.6% Age ≥65yr=86%	43%
Lilley et al. (2016) USA Cohort N=90	Median GCS=3 (IQR-3-3)	*GCS >8 at 72hr* (n=32) Median Age=80yr Male=62.5%, Female=37.5% *GCS ≤8 at 72hr* (n=29) Median Age=76yr Gender: Male=75.9%, Female=24.1%.	53%
You et al. (2016) China Cohort N=166	GCS 6-8=70% GCS 3-5=30%	*ICP monitoring* (n=80) Median Age=74yr (IQR 68-78) Male=54%, Female=46% *Non-ICP monitoring* (n=86) Median Age=76yr (IQR 69-82) Male=48%, Female=52%.	*ICP Monitoring*=38% *Non-ICP Monitoring*=51.2%
Wee et al. (2016) Singapore Case Series N=365	Mean GCS ≤60=5.0 Mean GCS >60=4.7	Mean Age=48.6yr Male=75.3%, Female=24.6% *Age ≤60yr* (n=249) *Age >60yr* (n=116)	Overall=49.3% *Age ≤60yr*=36.5% *Age >60yr*=76.7%
Yokobori et al. (2016) Japan Cohort N=1165	Severe TBI	*1998 Cohort* (n=306) Mean Age=75.3yr Male=60.05%, Female=35.94% *2004 Cohort* (n=380)	*1998 Cohort*=62.7% *2004 Cohort*=47.9% *2009 Cohort*=51.1%

Author Year Country Study Design Sample Size	Injury Severity	Age and Sex	In-Hospital Mortality Rate
		Mean Age=76.0yr Male=60%, Female=40% *2009 Cohort* (n=479) Mean Age=77.1yr Male=59.08%, Female=41.33%	
Miyata et al., (2016) Japan Cohort N=687	GCS 3-4=31% GCS 5-8=44% GCS 9-13=25%	Male=70%, Female=30% Before PS Matching *Therapeutic Temperature* (n=295) *Control* (n=392) After PS Matching *Therapeutic Temperature* (n=141) *Control* (n=141)	Before PS Matching=34% After PS Matching=29%
Wutzler et al. (2015) Germany Cohort N=8,629	ISS=19	Mean Age=54yr Male=67%, Female=33%	*60-69yr*=27.2% *70-79yr*= 34.5% *≥80yr*=46.6%
Haring et al. (2015) USA Cohort N=950,132	AIS ≥3=80%	≤79yr=47.4% ≥80yr=52.6% Male=47%, Female=53%	11.3%
Suehiro et al. (2014) Japan Cohort N=401	Severe TBI GCS <7	*Intensive Normothermia* (n=129) Mean Age=53.6yr Male=67.9%, Female=32.1% *Hypothermia* (n=47) Mean Age=46.9yr Male=100%, Female=0% *No temperature management* (n=225) Mean Age=61.5yr Male=70%, Female=30%	*Normothermia*=24% *Hypothermia*=34% *No Temperature Management*=30.7%
Bala et al., (2013) Israel Cohort N=417	Median AIS=4 (IQR 1-5) Mean ISS=22.9	Mean Age=76.9yr Male=56%, Female=44%	Overall=17.8% *70-79yr*=16.8% *≥80yr*=26.6%
Walder et al., (2013) Switzerland Cohort N=921	Median GCS=9 (IQR 4-14)	*Younger adults ≤65yr* (n=601) Median Age=40.3yr (IQR 25.4-54.3) Male=71.2% *Older adults >65yr* (n=320) Median Age=76.5yr (IQR 70.9-83.1) Male=61.6%	*<65yr Group*=24.5% *≥65yr Group*=40.9%

Author Year Country Study Design Sample Size	Injury Severity	Age and Sex	In-Hospital Mortality Rate
Ramanathan et al. (2012) USA Cohort N=2090	*Younger elderly* Mean GCS=5.3 *Middle Elderly* Mean GCS score=5.4 *Older Elderly* Mean GCS score=6.1	Male=57%, Female=43% *Younger Elderly 65-73yr* (n=1079) Mean Age=69.1yr *Middle Elderly 74-82yr* (n=1348) Mean Age= 78yr *Older Elderly 83-90yr* (n=799) Mean Age=85.8yr	*Younger Elderly 65-73yr* 56.8% *Middle Elderly 74-82yr* 66.8% *Older Elderly 83-90yr* 66%
Schonenberger et al. (2012) Switzerland Cohort N=3,226	Severe TBI	*<25yr* (n=413). Male=80.6%, Female=19.4% *25-49yr* (n=915). Male=79.6%, Female=20.4% *50-75yr* (n=604). Male=72.8%; Female=27.2% *>75yr* (n=158). Male=48.7%, Female=51.3%	*<25yr*= 28.8% *25-49yr*=24.7% *50-75yr*=36.6% *>75yr*=63.9%
Thompson et al. (2012) USA Cohort N=196	Mean GCS=9.9	*Age ≥55yr* Male=71%, Female=29%	31%
Schneider et al. (2012) USA Cohort N=38,675	Head AIS 4= >50%	Mean Age=78.4yr Male=49.42%, Female=50.57%	*Weekend*=9.3% *Weekday*=8.64%
Labib et al., (2011) Canada Case Series N=276	Mean GCS=12.4	Mean Age=81.5yr Male=59%, Female=41%	26.8%
Bhullar et al., (2010) USA Cohort N=2369	Mean GCS(>65yr) =12 Mean GCS(>80yr) =11	*Age < 17yr* (n=744) Mean Age=8yr *Age 17-64yr* (n=1,297) Mean Age=37yr *Age 65-80yr* (n=185) Mean Age=73yr *Age ≥80* (n=143) Mean Age=85yr	*<17yr*=6% *17-64yr*=9% *65-80yr*=21% *>80yr*=6%
Downey et al. (2009) Cohort USA N=328	Mean GCS=12.8	*Platelet Transfusion* (n=166) Mean Age=77.4yr Male=50%, Female=50% *No Platelet Transfusion* (n=162) Mean Age=73yr Male=53%, Female=47%.	*Platelets*=17.5% *No Platelets*=16.7%

Author Year Country Study Design Sample Size	Injury Severity	Age and Sex	In-Hospital Mortality Rate
Utomo et al. (2009) The Netherlands Case Series N=428	AIS 4=58.6% AIS 5=41.4%	*Age >64yr* Male=54.67%, Female=45.32%	27.6%
Mitra et al., (2008) Australia Case Series N=96	Severe TBI	Mean Age=Not Reported Male=54.2%, Female=45.8%	70.8%
Grandhi et al. (2008) USA Cohort N=1552	AC Group Mean GCS=11.6/AIS=4.0 NAC Group Mean GCS= 12.1/AIS=3.8	*Warfarin (AC) Group* (n=52) Mean Age=77.8yr Male=63.46%; Female=36.53% *No Warfarin (NAC) Group* (n=439) Mean Age=76.6yr Male=52.4%, Female=47.6%	*AC*=36.5% *NAC*=19.1%
Tokutomi et al. (2008) Japan Cohort N=797	*6-39yr* Mean GCS=6.0 *40-69yr* Mean GCS=5.7 *≥70yr* Mean GCS=6.1	*Age 6-39yr (n=302).* Male=82.1% *Age 40-69yr (n=306).* Male=76.8% *Age ≥70yr (n=189).* Male=61.3%	Overall=49.7% *Age 6-39yr*=34.1% *Age 40-69yr*=52.9% *Age ≥70yr*=69.3%
Ushewokunze et al. (2004) UK Case Series N=71	Severe TBI GCS= <8	Mean Age=77yr Male=49.3%, Female=50.7%	80%
Susman et al. (2002) USA Cohort N=11,722	GCS=12.15 ISS=17.52	*Older Adults* (n=3,203) Mean Age=78.3yr Male=50.4% Female=49.5% *Younger Adults* (N=8,569) Mean Age=34.8yr Male=65%, Female=35%	*Older Adults*=24% *Young Adults*=12.5%
Mosenthal et al. (2002) United States Cohort N=694	AIS head ≥3 ≤64yr GCS=10.2 >64yr GCS=10.5	*Age ≤64yr* (n=539) Male=60%, Female=40% *Age > 64yr* (n=155) Male=80%, Female=20%	*≤64yr Group*=14% Early death (<48hr) =65% *>64yr Group*=30% Early death (<48hr) =64%
Gomez et al. (2000) Spain Case Series	GCS ≤8	Male=78%, Female=22% *Age 15-25yr (n=327)* *Age 26-35yr (n=154)*	Overall=50.3% *Age 46-55yr*=37.5% *Age >55yr*=77%

Author Year Country Study Design Sample Size	Injury Severity	Age and Sex	In-Hospital Mortality Rate
N=797		*Age 36-45yr (n=102)* *Age 46-55yr (n=72)* *Age 56-65yr (n=66)* *Age >65yr (n=76)*	*Age >65yr*=86.8%
Kilaru et al., (1996) USA Case Series N=40	Severe TBI GCS=3-8	Mean Age=74.4yr Male=55%; Female=45%	68%
Pennings et al. (1993) USA Cohort N=92	*Elderly* Mean GCS=3.5 *Young* Mean GCS=3.6	*Elderly* (n=42) Mean Age=74yr Male-Female ratio 2:1 *Young* (n=50) Mean Age= 28yr Male-Female ratio 4:1	*Elderly Group*=79% *Young Group*=36%
Ross et al. (1992) USA Cohort N=195	GCS 3-8=48.7% GCS 9-12=21.5%	Mean Age=75.5yr Male=67%, Female=33%	20%
Kotwika & Jakubowski (1992) Poland Case Series N=136	GCS 3-5=24 GCS 6-8=29 GCS 9-12=53 GCS 13-15=30	*Age >70yr* Male=65%, Female=35%	52%
Davis & Acton (1988) USA Cohort N=62	Severe TBI PTA >1d	*Older adults* (n=26) Mean Age=65yr Sex=Not Reported *Younger adults* (n=26) Mean Age=21yr Sex=Not Reported	3.80%

*GCS=Glasgow Coma Scale, AIS=Abbreviated Injury Scale, ISS=Injury Severity Score, ICISS=ICD-based Injury Severity Score, PS=Propensity score.

Discussion

Older adults have higher rates of in-hospital mortality (Bhullar et al., 2010; Pennings et al., 1993; Susman et al., 2002; van Wessem & Leenen, 2022; Walder et al., 2013; Wutzler et al., 2015), doubling that seen in younger cohorts (Mosenthal et al., 2002; Tokutomi et al., 2008). In the studies presented above, mortality in-hospital among older adults ranged from 3.8 to 93%, with a sharp increased observed in populations over 80 years old. Further, those ≥70 years had 9 times higher chance of dying compared to individuals under the age of 49 years (van Wessem & Leenen, 2022). The presence of intracranial hypertension was also associated with increased mortality (42.7%) (Chico-Fernandez et al., 2020). Another factor that impacted mortality among older adults with head trauma was the timing of admission, with an increased mortality rate observed in those admitted on weekends (9.3%), when compared to those admitted on weekdays (8.64%) (Schneider et al., 2012).

Conclusions

There is level 2 evidence that older adults present with higher in-hospital mortality rates than their younger counterparts.

KEY POINTS

- In-hospital mortality rates tend to be higher in older adults when compared to younger populations.

Intensive Care Mortality

Intensive care for individuals who have sustained a moderate to severe TBI focuses on monitoring cerebral perfusion pressure (CPP), intracranial Pressure (ICP), cerebral metabolism and blood flow, as well as other critical biomarkers, with the aim to prevent secondary brain injury (Sheriff & Hinson, 2015). Older adults present with additional complexities for acute care management and are at risk of complications related to existing comorbidities; for instance, treatment with antithrombotic and anticoagulant drugs may result in increased risk of intracranial bleeding (Schumacher et al., 2017). Decisions regarding the admission of an older patient to the intensive care unit (ICU) are often difficult and need to take into account the wishes of patients and their families (Guidet et al., 2018). Table 4 presents findings related to intensive care mortality among older adults with moderate to severe TBI.

TABLE 4 | Intensive Care Mortality in Older Adults Post TBI

Author Year Country Study Design Sample Size	Injury Severity	Age and Sex	Intensive Care Mortality Rate
Chico-Fernandez et al., (2020) Spain Cohort N=465	Mean ISS=20.5 AIS Head=2.67	Mean Age=83.4yr Male=60%, Female=40%	15.5%
Maiden et al. (2020) Australia Cohort N=540	GCS 3-4=271 GCS 5-6=102 GCS 7-8=167	Age ≥65yr Male=55%, Female=45%	65%
Erlebach et al. (2017) USA	Median GCS=6 (IQR 3-9)	*Young group <39yr* (n=69) Mean Age=27yr Male=77%, Female=23%	*<39yr*=14% *40-64yr*=16% *≥65yr*=16%

Author Year Country Study Design Sample Size	Injury Severity	Age and Sex	Intensive Care Mortality Rate
Cohort N=174		*Middle-aged group 40-64yr* (n=55) Mean Age=52yr Male=76%, Female=24% *Elderly group ≥65yr* (n=50) Mean Age=77yr Male=62%, Female=38%	
Merzo et al. (2016) Sweden Cohort N=284	Median GCS=5 (IQR 5-6)	*Elderly group* (n=62) Mean Age=73yr Male=65%, Female=35% Younger group (n=222) Mean Age=39yr Male=84%, Female=16%	*Elderly Group*=6% *Younger Group*=4%
Dang et al., (2015) USA Cohort N=4,437	Median GCS=3 (IQR 3-6)	*ICP monitor* (n=495) Mean Age=66.7yr Male=72.3%, Female=27.7% *No ICP monitor* (n=3942) Mean Age=70.38yr Male=64.5%, Female=35.5%	*ICP Monitor*=38.8% *No ICP Monitor*=30.6%
Brazinova et al. (2010) Austria Case Series N=100	GCS 3=71% GCS 4=29%	*Age ≥66yr* Male=71%, Female=29%	76%
Bouras et al. (2007) Greece Cohort N=1926	*Group B1* GCS <13 =46.6% *Group B2* GCS <13=64.2%	*Group A* 14–64yr (n=1420) *Group B1* 65–74yr (n=238) *Group B2* ≥75yr (n=268) Sex=Not Reported	*Group A*=13.5% *Group B1*=29% *Group B2*=47.4%

*GCS=Glasgow Coma Scale, AIS=Abbreviated Injury Scale, ISS=Injury Severity Score, ICP=Intracranial Pressure

Discussion

Seven studies reported mortality in intensive care settings and rates ranging from 6% to 76%. Studies that compared younger versus older individuals reported higher mortality rates for those over 65 years of age, with a significant increased in those ≥75 years of age (Bouras et al., 2007). Admitting older individuals to the ICU is a complex decision that requires careful consideration of multiple factors such as expected survival and quality of life (Guidet et al., 2018). In the study by Bouras et al. (2007), younger individuals with GCS scores below 9 benefited more from treatment in the ICU when compared to older individuals, with those over 75 years old showing no differences in survival rates when ICU treatment was provided.

Conclusion

There is level 2 evidence that older adults admitted to intensive care experience higher mortality rates than younger patients.

KEY POINTS

- Mortality rates in the ICU tend to be higher for older individuals.

Surgical Mortality

Older adults with TBI, particularly those who present with frailty, may require higher levels of care to reduce surgical complications (Baggiani et al., 2022). The decision to perform neurosurgeries in older adults need to be considered carefully as they carry significant risk and the potential for poor outcomes (Manivannan et al., 2021). Table 5 presents findings related to surgical mortality among older adults with moderate to severe TBI.

TABLE 5 | Surgical Mortality in Older Adults Post TBI

Author Year Country Study Design Sample Size	Injury Severity	Age and Sex	Surgical Mortality Rate
Arac (2022) Turkey Case Series N=44	GCS=5-11	Mean Age=54.72yr (20-78yr) Male=59%, Female=41%	Decompressive craniectomy=34%
Akbik et al., (2019) USA Case Series N=62	TBI=95%, ABI=5% GCS<9=50% GCS>9=50%	Median Age=78 (IQR 65-93yr) Male=48%, Female=52%	Craniotomy perioperative mortality=39% At 3 months post surgery=44%
Lee et al. (2017) USA Cohort N=171	Mean GCS Aspirin=12.8 Mean GCS Non-Aspirin=11.4	*Perioperative Aspirin group* (n=87) Mean Age=78.3yr Male=57.5%, Female=42.5% *Non-Aspirin Group* (n=84) Mean Age=75.9yr Male=63.1%, Female=26.9%	Post-surgery mortality *Aspirin*=10.3% *Non-Aspirin*=20.2%
Wee et al. (2016) Singapore Case Series N=365	Mean GCS ≤60=5.0 Mean GCS >60=4.7	*Mean Age=48.6yr* Male=75.3%, Female=24.6% *Age ≤60* (n=249) Age >60 (n=116)	Post decompressive craniectomy=35.6%
Wan et al. (2016) China	GCS 3-5=40 GCS 6-8=72	*Conservative Treatment* (n=42) Mean Age=74.5yr Male=74%, Female=26%	Overall Mortality=53.6% *Conservative treatment*=88.1%

Author Year Country Study Design Sample Size	Injury Severity	Age and Sex	Surgical Mortality Rate
Cohort N=112		*Operation* (n=70) Mean Age=73yr Male=73%, Female=27% Craniotomy=14%, Craniectomy=86%	*Operation*=32.9%
Raj et al. (2016) Finland Case Series N=44	Median GCS=12 (IQR 8-13)	Traumatic subdural hematoma operation Median Age=81 (IQR 77-86) Male=52%, Female=48%	Post subdural hematoma operation mortality at 1 year=50%
Herou et al. (2015) Sweden Cohort N=119	GCS >10=56% GCS 6-9=37% GCS 3-5=7%	*Neurosurgical Treatment for Intracranial Hematoma* (n=97) Median Age=76yrs Sex=Not Reported *No Neurosurgical Treatment* (n=22) Median Age=81.5yrs Sex=Not Reported	30-day mortality post surgery=36% 90-day mortality=39% 180-day mortality=41%
Taussky et al. (2012) Case Series Switzerland N=37	Median initial GCS=8	Median Age=73yr (IQR 10yr) Male=46%, Female=54%	Craniotomy perioperative mortality=35%
De Bonis et al. (2011) Cohort Italy N=44	Mean GCS=6.7	Mean Age=76.6yr Male=59%, Female=41%	Mortality post decompressive craniectomy=48%

*GCS=Glasgow Coma Scale, AIS=Abbreviated Injury Scale, ISS=Injury Severity Score

Discussion

Nine studies reported post-surgical mortality among older adults. The mortality rate post-decompressive craniectomy or craniotomy ranged from 35% to 48% (Akbik et al., 2019; Arac, 2022; De Bonis et al., 2011; Taussky et al., 2012; Wee et al., 2016). Age was reported to be a crucial factor for mortality after surgery, with individuals over 55 years of age experiencing higher mortality rates, compared to their younger counterparts (Arac, 2022). Other factors associated with increased mortality in older patients included the presence of fixed and dilated pupils, lower pre-operative GCS score (Akbik et al., 2019), as well as the presence of intracranial hypertension in the ICU shortly after undergoing surgery (De Bonis et al., 2011). When comparing surgical to conservative treatment, Wan et al. (2016) found that surgery was associated with improved outcomes for older adults. The authors concluded that surgical care for this population should be considered on a case-by-case basis and should not necessarily be withheld based on age (Herou et al., 2015; Wan et al., 2016).

Conclusion

There is level 2 evidence that surgical mortality is higher among older adults, compared to younger adults, with mortality rates after decompressive craniectomy being greater than 30%.

KEY POINTS

- Surgical mortality tends to be higher in individuals aged 55 years and older, when compared to younger individuals. Surgery in older adults need to be considered on a case-by-case basis.

Post-Hospital Discharge Mortality

Studies have shown that older adults post TBI are at risk for rapid deterioration and poor functional outcomes (Mitra et al., 2008). Those who are discharged after hospitalization require appropriate support to prevent further injury, such as environmental modifications to reduce the risk of falls (Krishnamoorthy et al., 2015). For survivors of moderate to severe TBI, life after discharge may involve significant challenges for the patient and their caregivers, who may experience social, psychological and financial difficulties (Page et al., 2021). In addition, age-related factors such as the presence of comorbidities, regardless of injury severity, may impact recovery and contribute to higher rates of mortality for this population (McIntyre et al., 2014). Table 6 presents findings related to post-hospital discharge mortality among older adults with moderate to severe TBI.

TABLE 6 | Post-Hospital discharge Mortality in Older Adults Post TBI

Author Year Country Study Design Sample Size	Injury Severity	Age and Sex	Post-Discharge Mortality Rate
Erlebach et al. (2017) USA Cohort N=174	Median GCS=6 (IQR 3-9)	*Young group <39yr* (n=69) Mean Age=27yr Male=77%, Female=23% *Middle-aged group 40-64yr* (n=55) Mean Age=52yr Male=76%, Female=24% *Elderly group ≥65yr* (n=50) Mean Age=77yr Male=62%, Female=38%	At 6mo post-TBI=28% *Young group*=15% *Middle-aged group*=18% *Elderly group*= 56%
Merzo et al. (2016) Sweden Cohort N=284	Median GCS=5 (IQR 5-6)	*Elderly group* (n=62) Mean Age=73yr Male=65%, Female=35% Younger group (n=222) Mean Age=39yr Male=84%, Female=16%	At 6 mo: *Elderly Group*=25% *Young Group*=7%

Author Year Country Study Design Sample Size	Injury Severity	Age and Sex	Post-Discharge Mortality Rate
Anke et al. (2015) Norway Cohort N=163	Mean AIS head=4.3 Mean Lowest GCS=5.7	Mean Age=40.1yr Male=78%; Female=22% *Age Group 16-39yr* (n=89) *Age Group 40-64yr* (n=56) *Age Group ≥65yr* (n=18)	At 12mo=36%
Hirshon et al., (2013) USA Cohort N=60	Moderate to Severe TBI	*Deceased* (n=30) Mean Age=78yr Male=53%, Female=47% *Living* (n=30) Mean Age=77.1yr Male=53%, Female=47%	At 1-5yr post-injury=80%
Dhandapani et al., (2012) India Cohort N=244	Mild=25% Moderate=16% Severe=59%	Median Age=30yr (IQR 1-80) Male=214, Female=30	At 1mo: *Group <18yr*=15% *Group 18-59yr*=44% *Group >59yr*=52%
De Bonis et al. (2011) Cohort Italy N=44	Mean GCS=6.7	Mean Age=76.6yr Male=59%, Female=41%	At 1yr=77%
Patel et al. (2010) Cohort UK N=669	Median ISS=25 GCS <8	*Age 65-70yr* (n=137). Male/Female ratio 64:36 *Age 70-75yr* (n=147). Male/Female ratio 60:40 *Age 75-80yr* (n=160). Male/Female ratio 56:44 *Age ≥80yr* (n=225). Male/Female ratio 46:53	At 3mo: *65-70yr*=71.5% *70-75yr*=74.8% *75-80yr*=85% *>80yr*=87%
Brazinova et al. (2010) Austria Case Series N=100	GCS 3=71% GCS 4=29%	*Age ≥66yr* Male=71%, Female=29%	At 12mo=80%
Mohindra et al., (2008) India Cohort N=1071	GCS 3-8=32 GCS 9-12=2 GCS 13-15=11	*Older adult Group* (>70yr) (n=45) Mean Age=72.4yr Male=76%, Female=24% *Young Group* (20-40yr) (n=1026) Mean Age=Not Reported Sex: Not Reported.	At 6mo: *Older adult Group*=71.4% *Young Group*=25.1%
Colantonio et al. (2008) Canada Cohort N=3278	ISS >12 Head AIS ≥2=96.6%	Male=70%, Female=30% *Age 15-59yr* (n=2592) *Age ≥60yr* (n=685)	At 1yr=2.90 SMR

Author Year Country Study Design Sample Size	Injury Severity	Age and Sex	Post-Discharge Mortality Rate
Lee et al. (2006) Singapore Case Series N=528	GCS= <8	Mean Age=44.6yr Male=80%, Female=20% *0-20yr*=8.3% *21-40yr*=41.4% *41-60yr*=26% *>61yr*=24.6%	At 6mo=36.7%
Selassie et al. (2005) USA Cohort N=3679	AIS 1-2=40.2% AIS 3=17.5% AIS ≥4=42.4%	*Living patients* (n=3371) Male=66.2%, Female=33.8% *Deceased patients* (n=308) Male=53.6%, Female=46.4%	At 15mo: *15-34yr*=3.6% *35-54yr*=15.9% *55-74yr*=20.8% *≥75yr*=59.7%
Gan et al., (2004) Singapore Cohort N=324	*Older adults* Mean GCS=8.3 *Younger adults* Mean GCS=8.59	*Younger adults* (20-40yr) (n=148) Mean Age=29.22yr Male=87%, Female=13% *Older adults* (≥64yr) (n=65) Mean Age=73.86yr Male=58%, Female= 42%	At 6mo: *Older adults*=55.4% *Younger adults*=20.9%
Vollmer et al. (1991) USA Case Series N=661	*46-55yr* GCS 3-8=93.3% GCS 9-15=6.7% *≥56yr* GCS 3-8=90% GCS 9-15=10%	Sex=Not Reported *Age 16-26yr* (n=311) *Age 26-35yr* (n=151) *Age 36-45yr* (n=83) *Age 46-55yr* (n=45) *Age ≥56* (n=71)	At 6mo=38.1%

*GCS=Glasgow Coma Scale, AIS=Abbreviated Injury Scale, ISS=Injury Severity Score, SMR=standardized mortality rate

Discussion

In studies that reported mortality post-hospital discharge, older adults continue to show higher mortality rates than their younger counterparts (Erlebach et al., 2017; Gan et al., 2004; Mohindra et al., 2008; Selassie et al., 2005). Specifically, in studies comparing older to younger cohorts, mortality is significantly higher for those over 75 years old (Patel et al., 2010), regardless of injury severity upon admission. Though younger cohorts may initially present with more severe injuries, older adults may regress quickly and have worse outcomes such as need for intensive care (Erlebach et al., Gan et al., 2004); as well as decision-making related to the provision of aggressive forms of treatment or a more conservative therapeutic approach (Gan et al., 2004; Selassie et al., 2005). A significant predictive factor of mortality in these populations is the presenting GCS score at admission. Utilizing the GCS score to inform decisions regarding conservative or aggressive treatment options can positively impact mortality rates in elderly populations (Bala et al., 2013; Patel et al., 2010). The use of do-not-resuscitate (DNR) orders also requires consideration (Cherniack, 2002). DNR orders are often influenced by cultural and social factors, the preferences of older adults and their families, as well as the risk of poor quality of life and presence of multimorbidity (de Decker et al., 2014).

Conclusion

There is level 2 evidence that mortality post-hospital discharge can be higher in older adults compared to their younger counterparts, with higher rates observed in those over 75 years old.

KEY POINTS

- Post-hospital discharge mortality tends to be higher in older when compared to younger adults, with higher rates in those 75 years and older.

Comorbidities and Complications

Older adults often present with multiple medical comorbidities, adding a layer of complexity to an already vulnerable population. Cardiac conditions, such as hypertension, hyperlipidemia and ischemic heart disease are highly prevalent and are positive predictors for increased mortality rates in older patients (Ostermann et al., 2018; Salive, 2013). The high incidence of chronic concomitant conditions in older adults is also associated with adverse responses to therapeutic interventions and complications; and an increased risk of falls (Thompson et al., 2012). Hypertensive conditions, vascular diseases, hypercholesteremia, cancer, psychiatric comorbidities such as anxiety and depression, and previous instances of TBI are highly prevalent among older adults and can act as predictors of reduced functional independence and greater mortality rates (Gardner et al., 2018; Hammond et al., 2019; Ostermann et al., 2018; Pompucci et al., 2007; Salive, 2013). The presence of medical comorbidities in older adults with TBI has been associated with longer hospital stays and longer lengths of rehabilitation; there are greater diagnostic complexities with this group, differentiating cognitive impairment from preexisting conditions (e.g., dementia) versus that occurring as a result of TBI (Thompson et al., 2006). Table 7 presents findings related to the comorbidities and related complications in older adults with moderate to severe TBI.

TABLE 7 | Comorbidities and Complications in Older Adults Post TBI

Author Year Country Study Design Sample Size	Injury Severity	Age and Sex	Comorbidities and Complications
van Wessem & Leenen (2022) Netherlands Cohort N=391	AIS Head=3	*Age < 25yr* (n=76) Male=74%, Female=26% *Age 25-49yrs* (n=142) Male=74%, Female=26%	*Age <25yr* Pelvic fracture=33% MODS=9% ARDS=4% Infection=34%

Author Year Country Study Design Sample Size	Injury Severity	Age and Sex	Comorbidities and Complications
		Age 50-69y (n=101) Male=73%, Female=27% *Age ≥70yr* (n=72) Male=51%, Female=49%	Thromboembolism=4% *Age 25-49yr* Pelvic fracture=31% MODS=15% ARDS=4% Infection=42% Thromboembolism=11% *Age 50-69yr* Pelvic fracture=31% MODS=20% ARDS=5% Infection=50% Thromboembolism=6% *Age ≥70yr* Pelvic fracture=26% MODS=19% ARDS=3% Infection=42% Thromboembolism=3%
Kumar et al., (2019) USA Cohort N=2,134	Moderate to Severe TBI	Age= >50yr Sex=Not Reported	*Acute Hospital Complications* Respiratory infections Infections/parasites Nutritional deficiencies Fluid component imbalances Anemia *Chronic Disease* Hypertensive disease Diabetes Ischemic heart disease Disorders of lipid metabolism Nephritis
Kumar et al., (2018) USA Cohort N=2,134	Moderate to Severe TBI	Mean Age=65.9yr Male=66.9%, Total Female=33.1% *Age 50-54yr* (n=411) *Age 55-64yr* (n=718) *Age 65-74yr* (n=457) *Age75-84yr* (n=364) *Age 85+yr* (n=184)	*Age 50-54yr* Respiratory diseases=74.2% *Age 55-64yr* Respiratory diseases=64.6% *Age 65-74yr* Hypertensive disease=60.6% *Age75-84yr* Hypertensive disease=72.0% *Age 85+yr* Hypertensive disease=76.6%

Author Year Country Study Design Sample Size	Injury Severity	Age and Sex	Comorbidities and Complications
Flottemesch et al., (2017) USA Cohort N=140,766	Severe TBI	*Trauma center (TC)* (n=74,632) Male=63.4%, Female=36.6% *Non-Trauma Center (TC)* (n=66,134) Male=54.5%, Female=45.5%	*Trauma Center (TC)* Hypertension=46.3% Fluid and electrolyte disorders=19.2% Other neurologic conditions=18.2% Diabetes=14.8% *Non-Trauma Center* Hypertension=49.8% Fluid and electrolyte disorders=21.3% Other neurologic conditions=19.2% Diabetes=16.3%
Bala et al., (2013) Israel Cohort N=417	Median AIS=4 (IQR 1-5) Mean ISS=22.9	Mean Age=76.9yr Male=56%, Female=44%	Hospital complications=21.4% Pleural effusion=7.7% Pneumonia=5.0% Renal failure=2.6% Septicemia=1.2% Wound infection=1.0%
Hirshon et al., (2013) USA Cohort N=60	Moderate to Severe TBI	*Deceased* (n=30) Mean Age=78yr Male=53%, Female=47% *Living* (n=30) Mean Age=77.1yr Male=53%, Female=47%	*Deceased* Hypertension=87% Cardiac disease=47% Diabetes=40% *Living* Hypertension=77% Cardiac disease=47% Hypercholesterolemia=40%
Schonenberger et al. (2012) Switzerland Cohort N=3,226	Severe TBI	*<25yrs* (n=413). Male=80.6%, Female=19.4% *25-49yr* (n=915). Male=79.6%, Female=20.4% *50-75yr* (n=604). Male=72.8%; Female=27.2% *>75yr* (n=158). Male=48.7%, Female=51.3%	*<25yrs* Infectious complications=42.4% Sepsis=19.9% Pneumonia=25.8% *25-49yr* Infectious complications=43.8% Sepsis=20.9% Pneumonia=23.4% *50-75yr* Infectious complications=41.8% Sepsis=18.0% Pneumonia=23.2% *>75yr* Infectious complications=36.8% Sepsis=10.5% Pneumonia=24.6%

Author Year Country Study Design Sample Size	Injury Severity	Age and Sex	Comorbidities and Complications
Thompson et al. (2012) USA Cohort N=196	Mean GCS=9.9	*Age ≥55yr* Mean age=Not Reported Male=71%, Female=29%	Hypertension=41.4% Alcohol abuse=25.3% Cardiac arrhythmias=11.1% Coronary artery disease=9.9% Diabetes=9.3% Chronic pulmonary disease=8.6% Myocardial infarction=7.4% Rheumatoid arthritis=7.4% Other (neurological)=6.2% Anemia=5.6%
Labib et al., (2011) Canada Case Series N=276	Mean GCS=12.4	Mean Age=81.5yr Male=59%, Female=41%	Comorbid Hypertension=57.3% Coronary artery disease/congestive heart failure=34.4% Dementia=22.5% Diabetes=22.1%
Selassie et al. (2005) USA Cohort N=3679	AIS 1-2=40.2% AIS 3=17.5% AIS ≥4=42.4%	*Living patients* (n=3371) Male=66.2%, Female=33.8% *Deceased patients* (n=308) Male=53.6%, Female=46.4%	*Deceased patients* Cardiac comorbidity=48% Hypertension=29% Fluid and electrolyte imbalance=21% Cancer=13% Anemia, Diabetes or COPD=11% Psychiatric condition=8%
Mosenthal et al. (2002) United States Cohort N=694	AIS head ≥3 ≤64yr GCS=10.2 > 64yr GCS=10.5	*Age ≤64yr* (n=539) Male=60%, Female=40% *Age > 64yr* (n=155) Male=80%, Female=20%	*Age ≤64yr* Respiratory=10% Pneumonia=7% *Age >64yr* Respiratory=18% Pneumonia=12%

*GCS=Glasgow Coma Scale, PTA= Post Traumatic Amnesia, AIS=Abbreviated Injury Scale, ISS=Injury Severity Score, MODS=Multiple Organ Dysfunction Syndrome, ARDS=Adult Respiratory Distress Syndrome, COPD= Chronic obstructive pulmonary disease

Discussion

The risk of mortality among older adults may be significantly influenced by the presence of comorbid conditions. Patients with three or more concomitant diseases were four times more at risk for mortality at 1-year post-TBI than those patients without any comorbid conditions (Selassie et al., 2005). Individuals older than 70 years of age with TBI experienced a high risk of death as a result from complications arising from comorbid conditions (van Wessem & Leenen, 2020). Conditions that were significant positive predictors of unfavorable outcomes -such as mortality- included cardiac conditions, pulmonary conditions, hypertensive conditions, hospital acquired infections, septicemia, diabetes, and renal failure (Selassie et al., 2005; van Wessem & Leenen, 2020; Bala et al., 2013; Labib et al., 2011). Participants in the study by Kumar et al. (2019) presented with acute hospital complications such as respiratory infections, nutritional deficits and fluid imbalances. The authors noted that individuals with greater acute hospital complications were frequently men 50 to 64 years of age, were injured in a motor vehicle accident and had longer length of stay and post-traumatic amnesia (Kumar et al., 2019). In the studies presented above, hypertension was reported as the comorbidity with the highest incidence among older adults, with rates over 70% for the oldest cohorts, and over 80% for those individuals who did not survive post-TBI (Hirshson et al., 2013; Kumar et al., 2018).

Conclusion

There is level 2 evidence that having multiple comorbid conditions is associated with increased mortality rates and unfavorable outcomes in older adults who have sustained a TBI.

KEY POINTS

- The presence of comorbidities and medical complications may increase mortality rates in older adults who have sustained a TBI.

Acute Care

Epidemiological trends have shifted in the last decade, with the development of a higher incidence of TBI among older adults, most commonly secondary to falls, leading to hospitalization (Roozenbeek et al., 2013). In acute care, older trauma patients require aggressive triage and monitoring to avoid complications (Kuhne et al., 2005). When older adults present to the emergency department, their clinical presentation may not correlate with the true severity of the underlying injury (Barrett et al., 2022). This may lead to incorrect triage and inappropriate discharge home (Fröhlich et al., 2020). Furthermore, monitoring physiological indicators such as cerebral perfusion pressure in older adults can be challenging given the high incidence of comorbid conditions and polypharmacy that may affect the responsiveness of the cerebral vasculature (Thompson et al., 2006).

When providing acute care for older adults post-TBI, decision-making regarding treatment plans can be difficult and requires careful consideration and an individualized approach (Mitra et al., 2008). Despite improvements in care in recent decades, older adults -especially for those over 70 years old- continue to experience high rates of mortality and poor outcomes across all severities of TBI, (van Wessem & Leenen, 2022). Furthermore, older adults who present with frailty are more likely to experience poor outcomes and persistent deficits post-TBI that can reduce their quality of life (Baggiani et al., 2022). Decision making is complex and a degree of uncertainty exists regarding short-term and long-term outcomes among older adults post-TBI; therefore, goals of care need to be discussed with the patient and/or their substitute decision maker to ensure that the wishes of patients are taken into account (Lilley et al., 2016).

While decisions regarding whether or not to proceed with aggressive treatment as opposed to focusing on comfort care are complex and multifactorial; age biases still exist and need to be carefully considered (Skaansar et al., 2020). There is some controversy in the literature as to whether older adults should be treated aggressively or conservatively in the acute care setting, especially for those who have sustained very severe head injuries. While the management of older adults with TBI is challenging given the potential for slow recovery trajectories and poor outcomes, aggressive treatment may still lower short-term mortality in older adults (Waltzman et al., 2022). Table 8 presents findings related to the acute care management of older adults with moderate to severe TBI.

TABLE 8 | Acute Care Management of Older Adults Post TBI

Author Year Country Study Design Sample Size	Injury Severity	Age and Sex	Acute Care Management
Ruge et al. (2020) Sweden Cohort N=306	Mean AIS=4.3	*<60yr* (n=87) Mean Age=46yr Male=71.3%, Female=28.7% *≥60yr* (n=219) Mean Age=81yr Male=56.6%, Female=45.4%	Triage Priority (<60yr) Level I=34.5% Level II=32.2% Level III=33.3% Triage Priority (≥60yr) Level I=42.9% Level II=39.3% Level III=17.8%
You et al. (2016) China Cohort N=166	GCS 6-8=70% GCS 3-5=30%	*ICP monitoring* (n=80) Median Age=74yr (IQR 68-78) Male=54%, Female=46% *Non-ICP monitoring* (n=86) Median Age=76yr (IQR 69-82) Male=48%, Female=52%.	*ICP Monitoring* Mean Mannitol Dose=514g Mean Mannitol Duration=6.7d *Non-ICP Monitoring* Mean Mannitol Dose=840g Mean Mannitol Duration=8.4d
Yokobori et al. (2016) Japan Cohort N=1165	Severe TBI	*1998 Cohort* (n=306) Mean Age=75.3yr Male=64%, Female=36% *2004 Cohort* (n=380) Mean Age=76.0yr Male=60%, Female=40% *2009 Cohort* (n=479) Mean Age=77.1yr Male=59%, Female=41%	*1998 Cohort* Received Intensive treatment=67% ICP Monitoring=22.9% Temperature management=6.5% *2004 Cohort* Received Intensive treatment=58.7% ICP Monitoring=18.7% Temperature management=26.6% *2009 Cohort* Received Intensive treatment=71.4% ICP Monitoring=24.2% Temperature Management=30.1%

Author Year Country Study Design Sample Size	Injury Severity	Age and Sex	Acute Care Management
Suehiro et al. (2014) Japan Cohort N=401	Severe TBI GCS <7	*Intensive Normothermia* (n=129) Mean Age=53.6yr Male=67.9%, Female=32.1% *Hypothermia* (n=47) Mean Age=46.9yr Male=100%, Female=0% *No temperature management* (n=225) Mean Age=61.5yr Male=70%, Female=30%	*Normothermia* Received ICP Monitoring=42.6% Favorable outcome=33.3% *Hypothermia* Received ICP Monitoring=85.7% Favorable outcome=52.4% *No Temperature Management* Received ICP Monitoring=14.7% Favorable outcome=20.7%

*GCS=Glasgow Coma Scale, AIS=Abbreviated Injury Scale, ICP=Intracranial Pressure

Discussion

Older adults post TBI presenting may not be offered the same treatments as younger individuals. Persons with TBI older than 60 years of age are more likely to be triaged to a lower priority, experience longer wait times between admission and their first CT scan and are more likely to be offered conservative rather than aggressive treatment, when compared to younger individuals (Ruge et al., 2020; Yokobori et al., 2016). Consequently, irrespective of initial injury severity, mortality is higher for older adults, especially for those with AIS scores of 3 and greater (Ruge et al., 2020). Intensive treatments are significantly associated with lower mortality rates regardless of age (Yokobori et al., 2016). However, these treatments, while successful in preventing mortality can leave older survivors with significant disability. Evidence-based practices have been shown to help lower mortality risk associated with highly intensive treatments. Suehiro et al. (2014) found that individuals who received hypothermic therapy following evacuation of brain mass lesions had significantly lower mortality rates. Additionally, careful intracranial pressure (ICP) monitoring and a reduction in mannitol dose given can help induce more efficient cerebrospinal fluid (CSF) draining and dramatically improve mortality outcomes. It is important to highlight that age should not be the sole criterion used when making triage or treatment decisions (Ruge et al., 2020; Yokobori et al., 2016).

Conclusion

There is level 2 evidence that older adults may be triaged to a lower priority in emergency departments and offered conservative rather than aggressive acute care treatment.

KEY POINTS

- Injury severity may be underestimated in older adults during triage in emergency care, thus contributing to increased mortality.

Neurosurgical Care

Despite the benefits of neurosurgical care for individuals with TBI who present with elevated intracranial pressure (ICP), there is an associated risk of complications and adverse effects (Servadei et al., 2007). Neurosurgical treatment in older individuals can be challenging, due to multimorbidity and the associated risk of poor outcomes and high mortality in this population (Edlmann & Whitfield, 2020). Decisions regarding hospitalization and whether to proceed with neurosurgery are critical for older adults' outcomes post-TBI; however, older adults often experience barriers to care due to factors such as a lack of guidelines and protocols for use in older age and the presence of clinician bias (Barrett et al., 2022). High ICP is considered the most common cause of death and disability among those who have sustained a severe TBI; while this is usually managed using non-surgical strategies (e.g., sedation, hypothermia), neurosurgical care (e.g., decompressive craniectomy) may be needed when first and second line therapies fail (Sahuquillo & Dennis, 2019). Decompressive craniectomy is frequently used to control ICP by allowing the brain tissue to expand and reducing risk of herniation; however, it may not result in reduced risk of death for those with very severe injuries (Wang et al., 2016).

Age is an important factor impacting mortality and functional outcomes of individuals post-craniectomy, with increased surgical mortality rates observed in those 55 years of age and older (Arac, 2022). While surgical treatment has the potential to reduce mortality and improved outcomes in older adults (Wan et al., 2016), surgical therapies such as depressive craniectomy are not commonly performed in those over 65 years (Lee et al., 2014; Skaansar et al., 2020; Taussky et al., 2012). Decisions regarding withholding life-saving surgeries on the basis of age need to be ethical and carefully considered (Lee et al., 2014). Table 9 presents findings related to the neurosurgical care of older adults with moderate to severe TBI.

TABLE 9 | Neurosurgical Care for Older Adults Post TBI

Author Year Country Study Design Sample Size	Injury Severity	Age and Sex	Neurosurgical Care Management
Arac (2022) Turkey Case Series N=44	GCS=5-11	Mean Age=54.72yr (20-78yr) Male=59%, Female=41%	*Decompressive Craniectomy* Recommended for: 1. Patients ≤ 55 years old. 2. Patients with cerebral edema on CT scan and GCS ≥8. 3. Before signs of brain herniation, if possible (within 24 hours).
Skaansar et al., (2020) Norway Cohort N=1,571	GCS=10-12.5	*Age 15-24yr* (n=179). Male=74.9% *Age 25-34yr* (n=168). Male=79.8% *Age 35-44yr* (n=153). Male=81.7% *Age 45-54yr* (n=197). Male=73.6% *Age 55-64yr* (n=258). Male=75.6% *Age 65-74yr* (n=297). Male=67.7% *Age 75-84yr* (n=197). Male=56.9%	*Decompressive craniectomy* performed in 14% Not performed in any patients ≥ 75 years. *Surgical Evacuation of intracranial mass*

Author Year Country Study Design Sample Size	Injury Severity	Age and Sex	Neurosurgical Care Management
		Age ≥85yr (n=122). Male=37.7%	Performed in 14%
Lee et al. (2017) USA Cohort N=171	Mean GCS Aspirin=12.8 Mean GCS Non-Aspirin=11.4	*Perioperative Aspirin Group* (n=87) Mean Age=78.3yr Male=57.5%, Female=42.5% *Non-Aspirin Group* (n=84) Mean Age=75.9yr Male=63.1%, Female=26.9%	*Craniectomy, Craniotomy and Burr Hole* *Aspirin* Post-operative intracranial haemorrhage=17.2% *Non-Aspirin* Post-operative intracranial haemorrhage=26.2%
Wan et al. (2016) China Cohort N=112	GCS 3-5=40 GCS 6-8=72	*Conservative Treatment* (n=42) Mean Age=74.5yr Male=31, Female=11 *Operation* (n=70) Mean Age=73yr Male=51, Female=19	*Operation* Craniotomy (n=10) Craniectomy (n=60) Unfavorable outcome=52.9% *Conservative Treatment* Unfavorable outcome=95.2%
Wutzler et al. (2015) Germany Cohort N=8,629	ISS=19	Mean Age=54yr Male=67%, Female=33% *Operative Treatment* Mean Age=55.1yr *Non-Operative Treatment* Mean Age=65.6yr	*Operative Treatment* Persistent Vegetative State=8.2% *Non-Operative Treatment* Persistent Vegetative State=3.1%
Lee et al., (2014) Korea Case Series N=227	Severe TBI	Age >60yr	*Conservative Treatment* (n=174) *Burr Hole* (n=28) *Craniotomy* (n=25)
Taussky et al. (2012) Case Series Switzerland N=37	Median initial GCS=8	Median Age=73yr (IQR 10yr) Male=17, Female=20	Decompressive craniectomy=38% Median Time to Surgery= 4h (IQR 3) Perioperative morbidity=32% Good Surgical Outcome=41%
De Bonis et al. (2011) Cohort Italy N=44	Mean GCS=6.7	Mean Age=76.6yr Male=26, Female=18	Decompressive craniectomy=4.6% Length of Surgery=152min

Author Year Country Study Design Sample Size	Injury Severity	Age and Sex	Neurosurgical Care Management
			Post-operative unfavorable outcome=82%

*GCS=Glasgow Coma Scale, ISS= Injury Severity Scale, CT=computerized tomography

Discussion

Surgical treatments following TBI can reduce mortality and improve outcomes regardless of age (Taussky et al., 2012; Wan et al., 2016; Wutzler., 2015). Despite this, surgical therapies such as depressive craniectomy are not frequently done in individuals older than 65 years (Lee et al., 2014; Skaansar et al., 2020; Taussky et al., 2012). Management intensity tends to decrease with increasing age as there are higher risks of post-operative infection, as well reduced recovery capacity of the brain that may lead to unfavourable outcomes for older patients (De Bonis et al., 2011; Skaansar et al., 2020). However, several poor outcomes following surgery are often a result of uncontrollable brain swelling or a deterioration of a comorbid condition rather than the results of a complication related to the actual injury (Wan et al., 2016; Taussky et al., 2012). In fact, lack of surgical treatment, or rather pursuing a more conservative treatment is often a significant predictor of poor outcome (Skaansar et al., 2020; Wan et al., 2016; Wutzler., 2015). Arac et al. (2022) found that older individuals (>55 years) had longer wait times between injury and surgery times, which was associated with an increased risk of neurological regression and mortality. There are factors other than age that may serve as more accurate predictors of outcome post-surgery. Wan et al. (2016) found that, among individuals older than 65 years, those with GCS scores below 6 were 18.7 times more likely to have unfavourable outcomes and had a 10.7 times higher chance of mortality. In contrast, those with GCS scores above 8 may significantly benefit from more aggressive treatment options (Taussky et al., 2012). Another strong predictor of outcome is abnormal pupillary reactivity; those with aniscoria or areactive pupils are more at risk for death than those without these findings (Lee et al., 2014; Taussky et al., 2012).

Conclusion

There is level 2 evidence that more aggressive treatments, including neurosurgical intervention, may increase survival in older adults with moderate to severe TBI; particularly patients with GCS >8.

KEY POINTS

- While there are associated risks, older adults may still benefit from neurosurgery; particularly those with higher GCS scores (>8).

Hospitalization

Hospitalizations post-TBI in Canada have been increasing among older adults in recent years, with 82% occurring secondary to falls (Cusimano et al., 2020), and the highest rate of TBI-related emergency department visits and hospitalization are occurring among those over 75 years of age. Similarly, in the United states, TBI-related hospitalizations after falls were more likely to occur among adults ≥75 years of age (Peterson et al., 2019). Older adults show slower recovery trajectories than their younger counterparts, with additional complexities related to comorbidities and difficulty differentiating TBI symptoms from those caused by pre-existing conditions or medications (Waltzman et al., 2022). Moreover, older adults are at higher risk of experiencing complications during their hospital stay and have a higher risk of risk of readmission (Brito et al., 2019). Table 10 presents findings related to the hospitalization and readmission of older adults with moderate to severe TBI.

TABLE 10 | Hospitalization and Readmission of Older Adults Post TBI

Author Year Country Study Design Sample Size	Injury Severity	Age and Sex	Hospitalization and Readmission
		Hospitalization	
Fu et al., (2017) Cohort Case Series N=43,823	Median ICISS=0.8	Male=52%, Female=48% *Survivors* Median Age =79yr (IQR 12) *Non-Survivors* Median Age =83yr (IQR 12)	Hospitalization rate=6% per year (24% overall increase) *Fall Injuries* Median Length of Stay=8.0 (IQR 17.0) *Non-Fall Injuries* Median Length of Stay=7.0 (IQR 15.0)
Fu et al., (2015) Canada Cohort N=116,614	Mean ICISS=0.76	*Survivors* (n=106,429) Mean Age=48yr Male=65%, Female=35% *Non survivors* (n=10,185) Mean Age=68.8yr Male=62%, Female=38%	Hospitalization over a 5-year period: Severe TBI=16% Moderate TBI=4% Mild TBI=3%
		Hospital Readmission	
Li et al. (2018) USA Cohort N=52,877	Severity** Minor=26.9% Moderate=42.3% Major=23.5% Extreme=7.3%	Male=59%, Female=41%** *Group 1 18-40yr* (n=11305) *Group 2 41-65yr* (n=14495) *Group 3 66-75yr* (n=7485) *Group 4 ≥76yr* (n=19592)	*Multiple Readmissions* Female=63.6% ED visit=87.6% Reasons for readmission (≥66yr): circulatory diseases, respiratory diseases, infection, genitourinary diseases.
Saverino et al.,	*Age ≥65yr*	*Age <15yr.* Male=64%, Female=36%	*Rehospitalization (Age ≥65yr)*

Author Year Country Study Design Sample Size	Injury Severity	Age and Sex	Hospitalization and Readmission
(2016) Canada Case Series N=29,269	AIS ≥4 Males=71.9% AIS ≥4Females=63.5%	*Age 15-24yr.* Male=79%, Female=21% *Age 25-49yr.* Male=76%, Female=24% *Age 50-64yr*. Male=71%, Female=29% *Age ≥65yr.* Male=52%, Female=48%	At 1yr=35.15% At 3yr=54.3%
Fawcett et al., (2015) USA Cohort N=14,536	AIS ≤3=12,767 AIS >3=1,769 ISS >9=65.89%	Male=42%, Female=58% *Age 55-64yr* (n=3,821) *Age 65-74yr* (n=2,946) *Age 75-84yr* (n=3,787) *Age ≥85yr* (n=3,981)	*Age 55-64yr* Readmitted at 1yr=20.6% *Age 65-74yr* Readmitted at 1yr=20.1% *Age 75-84yr* Readmitted at 1yr=28.6% *Age ≥85yr* Readmitted at 1yr=30.7%

*GCS=Glasgow Coma Scale, ED=Emergency Department, AIS=Abbreviated Injury Score, ISS=injury Severity Score, ICISS=ICD-based Injury Severity Score.
**At 30d readmission

Discussion

TBI in older adults is often a direct consequence of a fall from a standing height (Fu et al., 2017); this mechanism of injury accounts for roughly 80% of TBI hospitalizations and 85% of TBI-related in-hospital mortality annually (Fu et al., 2015; Fu et al., 2017). The injury severity resulting from such falls increases with patient age (Saverino., 2016). Older adults, specifically those 75 years of age and older are more likely to be readmitted to the hospital post-TBI than younger individuals (Fawcett et al., 2015; Fu et al., 2017; Saverino et al., 2016), with secondary circulatory conditions, pre-existing psychiatric comorbidities and age itself acting as significant predictors of rehospitalization (Saverino et al., 2016). Interestingly, discharge to skilled nursing facilities has been shown to be a significant predictor for hospital readmission (Fawcett et al., 2015) likely due to reduced independence among those discharged to care facilities as opposed to home. Recommendations to help mitigate the risk of readmission have included exercise programs that help improve strength and balance, safety assessments, vision assessments, medication review, educational programs to promote safer behaviour, enhanced transition/discharge care, and improved access to services for post-acute care needs (Fu et al., 2017; Saverino et al., 2016).

Conclusion

There is level 2 evidence that older adults with TBI may be at a higher risk of hospitalization and readmission than younger adults.

KEY POINTS

- Older adults with moderate to severe TBI may experience higher rates of hospitalization and readmission.

Discharge Disposition

There are multiple pathways of care for individuals with moderate to severe TBI. Following discharge from hospital, patients may go home, to inpatient rehabilitation or to community care (e.g., nursing care facilities, retirement home, home care) (de Koning et al., 2015). Discharge disposition post-TBI may be influenced by factors such as availability of resources, insurance coverage, and environmental factors (Zarshenas et al., 2019). For instance, in the United States, factors such as race and insurance status have been shown to be strong predictors for discharge to rehabilitation settings among adults with TBI (Asemota et al., 2013). Older adult survivors of TBI may present with worse functional outcomes than younger persons (Susman et al., 2002). Proper discharge planning is critical to ensure a smooth transition and special attention should be given to a person's level of functional independence level, clinical presentation and social condition, as well as the expectations of both patients and families (Zurlo & Zuliani, 2018). Table 11 presents findings related to the discharge disposition of older adults with moderate to severe TBI.

TABLE 11 | Discharge Disposition of Older Adults Post TBI

Author Year Country Study Design Sample Size	Injury Severity	Age and Sex	Discharge Disposition
van Wessem & Leenen (2022) Netherlands Cohort N=391	AIS Head=3	*Age < 25yr* (n=76). Male=74%, Female=26% *Age 25-49yr* (n=142). Male=74%, Female=26% *Age 50-69yr* (n=101). Male=73%, Female=27% *Age ≥70yr* (n=72). Male=51%, Female=49%	Home=34%
Harada et al. (2021) Japan Cohort N=63	Mean GCS=8.9	Male=83.3%, Female=12.7% *≤24yr* (n=14) *Age 25-44yr* (n=15) *Age 45-64yr* (n=15) *Age ≥65yr* (n=19)	*≤24yr* Home=100% *Age 25-44yr* Home=86.7% *Age 45-64yr* Home=80% *Age ≥65yr* Home=68.40% Nursing Facility=31.6%
Gorman et al. (2020) USA Cohort N=3292	Median GCS=9	*Non-Latino White* (n=2550) Median Age=76yr, (IQR 70-83yr) Male=53%, Female=47% *Black (n=259)* Median Age=75yr, (IQR 69-81yr) Male=58%, Female=42% *Asian* (n=170) Median Age=77yr, (IQR 70-82.2yr) Male=56%, Female=44%	*Non-Latino White* Home=19.7% Skilled Nursing Facility=27.8% Rehabilitation=20.4% *Black* Home=24.3% Skilled Nursing Facility=34% Rehabilitation=14.3% *Asian*

Author Year Country Study Design Sample Size	Injury Severity	Age and Sex	Discharge Disposition
		Latino (n=236) Median Age=74, (IQR 68-80yr) Male=70%, Female=30% *Other* (n=77) Median Age=76, (IQR 69-81yr) Male=58%, Female=42%	Home=24.1% Skilled Nursing Facility=27.6% Rehabilitation=18.8% *Latino* Home=28% Skilled Nursing Facility=27.1% Rehabilitation=14.8% *Other* Home=27.3% Skilled Nursing Facility=31.2% Rehabilitation=13%
Akbik et al., (2019) USA Case Series N=62	TBI=95%, ABI=5% GCS<9=50% GCS>9=50%	Median Age=78 (IQR 65-93yr) Male=48%, Female=52%	Hospice=5% Long-term Acute Care=6% Skilled Nursing Facility=21% Inpatient Rehabilitation=26% Home=3%
Kim et al., (2019) South Korea Cohort N=92	Severe=26.1% Moderate=35.9% Mild=38%	Male=76.1%, Female=23.9% *Young group* (n=52) Median Age=52.5yr *Elderly group* (n=40) Median Age=75yr	*Elderly Group* Home=28.8% *Young Group* Home=35%
Enumah et al., (2018) USA Case Series N=50,342	AIS ≥3 ISS 16-24=54.6%	Male=58.4%, Female=41.6% *Age 65-74*=31.4% *Age 75-84%*=43.1% *Age ≥85*=25.5%	*2005 Cohort* Hospice=10% *2011 Cohort* Hospice=16%
Lilley et al. (2018) USA Cohort N=34,691	Severe TBI	Median Age=79yr (IQR 72-84) Male=59.1%, Female=40.8%	Hospice=58%
Li et al. (2018) USA Cohort N=52,877	Severity** Minor=26.9% Moderate=42.3% Major=23.5% Extreme=7.3%	*At 30d Readmission* Male=59%, Female=41% *Group 1 18-40yr* (n=11305) *Group 2 41-65yr* (n=14495) *Group 3 66-75yr* (n=7485) *Group 4 ≥76yr* (n=19592)	At 30d: Home=59.3% At 60d: Home=59.4% At 90d: Home=59.7%
Fu et al., (2017) Cohort	Median ICISS=0.8	Male=52%, Female=48% *Survivors*	Home=50% In-patient hospital facility=14%

Author Year Country Study Design Sample Size	Injury Severity	Age and Sex	Discharge Disposition
Case Series N=43,823		Median Age =79yr (IQR 12) *Non-Survivors* Median Age =83yr (IQR 12)	Long-term care=18% Outpatient hospital=2%
Fawcett et al., (2015) USA Cohort N=14,536	AIS ≤3=12,767 AIS >3=1,769 ISS >9=65.89%	Male=42%, Female=58% *Age 55-64yr* (n=3,821) *Age 65-74yr* (n=2,946) *Age 75-84yr* (n=3,787) *Age ≥85yr* (n=3,981)	Home=32.9% Home with assistance=7.9% Rehabilitation=5.6% Skilled Nursing Facility=46.1% Hospice/Other=7.5%
Meagher et al., (2015) USA Cohort N=299,205	ISS >9=76.2% Median GCS motor=6	*≥ 65yr* (n= 56,235) Mean Age=77.9yr	Home=44.5% Home with assistance=6.4% Skilled Nursing Facility=33.8% Inpatient Rehabilitation=15.3%
Anke et al. (2015) Norway Cohort N=163	Mean AIS head=4.3 Mean Lowest GCS=5.7	Mean Age=40.1yr Male=78%; Female=22% *Age group 16-39yr* (n=89) *Age Group 40-64yr* (n=56) *Age Group ≥65yr* (n=18)	Home=4% Rehabilitation=48% Other acute hospital=48%
Nott et al., (2015) Australia Cohort N=2,545	*Age <35yr* PTA <4wk=43% PTA 1-6mo=44% PTA >6mo=12% *Age ≥35yr* PTA <4wk=36% PTA 1-6mo=50% PTA >6mo=14%	*Age <35yr* (n=1419) Median Age=23yr Male=82%, Female=18% *Age ≥35yr* (n=1126) Median Age=47yr Male=80%, Female=20%	*Age <35yr* Home=76% Rehabilitation=19% Nursing Home=5% *Age ≥35yr* Home=72% Rehabilitation=17% Nursing Home=12%
Fu et al., (2015) Canada Cohort N=116,614	Mean ICISS=0.76	*Survivors* (n=106,429) Mean Age=48yr Male=65%, Female=35% *Non survivors* (n=10,185) Mean Age=68.8yr Male=62%, Female=38%	*Survivors:* Home=57% Home with assistance=8.4% Inpatient rehabilitation=12% Long-term care=10% Hospice/Palliative care=4%
Bhullar et al., (2010) USA Cohort N=2369	Mean GCS(>65yr) =12 Mean GCS(>80yr) =11	*Age < 17yr* (n=744) Mean Age=8yr *Age 17-64yr* (n=1,297) Mean Age=37yr *Age 65-80yr* (n=185) Mean Age=73yr *Age ≥80yr* (n=143)	*<17yr* Home=84% *17-64yr* Home=77% *65-80yr* Home=50% *≥80yr*

Author Year Country Study Design Sample Size	Injury Severity	Age and Sex	Discharge Disposition
		Mean Age=85yr	Home=51%
Yap & Chua (2008) Singapore Case Series N=52	Mild=42.9% Moderate=26.5% Severe=28.6% Very Severe=1%	Mean Age=68.3yr Male=71%, Female=29%	Home=54% Home with assistance=35% Long-term Care=7.7%
Grandhi et al. (2008) USA Cohort N=1552	AC Group Mean GCS=11.6/AIS=4.0 NAC Group Mean GCS= 12.1/AIS=3.8	*Warfarin (AC) Group* Mean Age=77.8yr Male=63%; Female=37% *No Warfarin (NAC) Group* Mean Age=76.6yr Male=52%, Female=48%	*Warfarin (AC) Group* Discharged Home=42.4% *No Warfarin (NAC) Group* Discharged home=57.6%
Frankel et al. (2006) USA Cohort N=534	Mean GCS=11	*Younger patients* (n=267) Mean Age=30.2yr Male=74.5%, Female=25.5% *Older patients* (n=267) Mean Age=66.6yr Male=68.9%, Female=31.1%	*Younger patients* 94.4% *Older Patients* 80.5%
Mosenthal et al. (2002) United States Cohort N=694	AIS head ≥3 ≤64yr GCS=10.2 > 64yr GCS=10.5	*Age ≤64yr* (n=539) Male=60%, Female=40% *Age > 64yr* (n=155) Male=80%, Female=20%	*Age ≤64yr* Nursing home=0.6% Rehabilitation facilities=14.3% *Age >64yr* Nursing home=10% Rehabilitation facilities=26.9%
Davis & Acton (1988) USA Cohort N=62	Severe TBI PTA >1d	*Older Adults* (n=26) Mean Age=65yr *Younger Adults* (n=26) Mean Age=21yr	Home=62% Skilled Nursing Facility=26.9%

*GCS=Glasgow Coma Scale, AIS=Abbreviated Injury Score, PTA=Post-traumatic Amnesia
**At 30d readmission

Discussion

Older adults are more likely to be discharged to non-home facilities such as nursing hospitals, hospice/ palliative long term care facilities or inpatient rehabilitation units often than younger adults post-TBI (Bhullar et al., 2010; Davis & Acton, 1988; Frankel et al., 2006; Fu et al., 2015; Harada et al 2021). Older adults also have the highest rates of hospice enrollment compared to other age cohorts (Enumah et al., 2018; Lilley et al., 2018). Further, among those who were well enough to be discharged home, assistive care was still needed for nearly 50% of patients (Davis & Acton, 1998). In contrast to most literature, one study reported that both older and younger cohorts undergo similar distribution spreads to discharge locations and were equally likely to go home (Nott et al., 2015). In the study by Nott et al. (2015), while participant data on causes of death was presented for three age groups (16-29yr, 30-49yr, ≥50yr), other analyses divided participants only into two groups (<35yr, ≥35yr); therefore, results of this study need to be interpreted with caution.

Socioeconomic factors may also influence discharge disposition among older adults. Meagher et al. (2015) found that older age Hispanic and Black patients were significantly less likely to be discharged to higher levels of rehabilitations. Gorman et al. (2020) also examined disparities and found that Non-Latino White and Black individuals were most likely to be discharged to a skilled nursing facility, when compared to Asian and Latin American individuals. Studies, in Norway and Singapore respectively, investigating functional outcomes and discharge location found that individuals discharged directly to rehabilitative units or nursing home facilities demonstrated significant functional improvements within a year post injury (Anke et al., 2015; Yap & Chua, 2008).

Conclusion

There is level 2 evidence that older adults with TBI may be more likely to be discharged to non-home facilities than younger individuals, and those that are discharged home may require additional supports.

KEY POINTS

- Older adults with moderate to severe TBI may be more likely to be discharged to long-term care, skilled nursing facilities and palliative care than younger individuals, and may be more likely to require support when discharged home.

Recovery Outcomes

Individuals who have sustained a TBI, particularly those with more severe injuries, often present with lasting long-term impairments and disability affecting activities of daily living, mental health and community reintegration (Mostert et al., 2022). When compared to younger individuals, older adults present with worse outcomes, including functional, cognitive and psychosocial outcomes (Harada et al., 2021). While older individuals with TBI may experience similar gains in rehabilitation as their younger counterparts, these improvements are tend to be slower (Frankel et al., 2006). Outcomes are particularly adverse for individuals 80 years of age and older, with high rates of mortality regardless of TBI severity and treatment received (Solomon et al., 2019). In a study on outcomes post-TBI across all severities, Prasad et al. (2018) found that predictors of poor outcomes in older adults included age ≥75 years, a GCS score <9, concomitant brainstem injury, acute subdural hematoma and associated comorbidities. While rehabilitation for older adults has been associated with increased lengths of stay and cost, delivering rehabilitation services for this population is critical to facilitate the best possible recovery and function post-TBI (Stein et al., 2018).

Glasgow Outcome Scale

The Glasgow Outcome Scale (GOS), and its extended version (GOSE) (Wilson et al., 1998) are commonly used outcome measures for recovery and function post brain injury, with higher scores indicating good recovery. The, original and extended, GOS are the most popular clinician-reported primary outcome measures used in clinical trials, and they assess disability, quality of life and social participation (GOS 1=death; GOS 2=Persistent Vegetative State; GOS 3=Severe Disability; GOS 4= Moderate Disability; GOS 5=Good Recovery) (McMillan et al., 2016). TBI trials have analyzed groups using the GOS into two categories: Unfavorable (Death, Vegetative State, or Severe Disability) versus Favorable (Moderate Disability or Good Recovery) (Weir et al., 2012). Table 12 presents findings related to recovery outcomes in older adults with moderate to severe TBI, as measured by the GOS, with higher scores indicating more favorable recovery.

TABLE 12 | Glasgow Outcome Scale in Older Adults post TBI

Author Year Country Study Design Sample Size	Injury Severity	Age and Sex	Functional Outcomes Findings
van Wessem & Leenen (2020) Netherlands Cohort N=391	AIS Head=3	*Age < 25yr* (n=76) Male=74%, Female=26% *Age 25-49yrs* (n=142) Male=74%, Female=26% *Age 50-69y* (n=101) Male=73%, Female=27% *Age ≥70yr* (n=72) Male=51%, Female=49%	*Age 50-69y* GOS 2=1% GOS 3=70% GOS 4=9% GOS 5=20% *Age 70+yr* GOS 2=3% GOS 3=87% GOS 4=0% GOS 5=11%
Maiden et al. (2020) Australia Cohort N=540	GCS 3-4=271 GCS 5-6=102 GCS 7-8=167	*Age ≥65yr* Male=55%, Female=45%	At 6mo: GOSE 1=85.1% GOSE 2-4=8.8% GOSE 5-8=6.2% At 12mo: GOSE 1=86.3% GOSE 2-4=6.4% GOSE 5-8=7.3% At 24mo: GOSE 1=87.2% GOSE 2-4=6.4% GOSE 5-8=6.4%
Akbik et al., (2019) USA	TBI=95%, ABI=5% GCS<9=50% GCS>9=50%	Median Age=78 (IQR 65-93yr) Male=30, Female=32	At Discharge: GOS 1=39% GOS 2=6%

Author Year Country Study Design Sample Size	Injury Severity	Age and Sex	Functional Outcomes Findings
Case Series N=62			GOS 3=42% GOS 4=10% GOS 5=3%
Kim et al., (2019) South Korea Cohort N=92	Severe=26.1% Moderate=35.9% Mild=38%	Male=76.1%, Female=23.9% *Young group* (n=52) Median Age=52.5yr *Elderly group* (n=40) Median Age=75yr	At discharge: *Young Group* GOS 1=0% GOS 2=17.5% GOS 3=37.5% GOS 4=22.5% GOS 5=22.5% *Elderly Group* GOS 1=0% GOS 2=32.7% GOS 3=38.5% GOS 4=23.1% GOS 5=5.8%
Ostermann et al., (2018) Austria Case Series N=292	*Survived* AIS Head=3.39 *Died* AIS Head=4.39	*Survived* (n=215) Mean Age=79.8yr Male=41%, Female=59% *Died* (n=77) Mean Age=83.4yr Male=48%, Female=52%	Survivors at discharge: GOS 2=6.2% GOS 3=11% GOS 4=8.2% GOS 5=48.3%
Gross & Amsler (2018) Switzerland Cohort N=326	Mean GCS=12.20 Mean ISS=15.50 Mean AIS Head=2.71	Male=67.2%, Female=32.8% *Group < 65yr* (n=216) Mean Age=43.24yr *Group ≥65yrs* (n=110) Mean Age=73.56yr	*Group < 65 years* Mean GOS=4.78 *Group > 65 years* Mean GOS=4.76
Erlebach et al. (2017) USA Cohort N=174	Median GCS=6 (IQR 3-9)	*Young group <39yr* (n=69) Mean Age=27yr Male=77%, Female=23% *Middle-aged group 40-64yr* (n=55) Mean Age=52yr Male=76%, Female=24% *Elderly group 65+yr* (n=50) Mean Age=77yr Male=62%, Female=38%	*Young group <39yr* Favorable (GOS 4-5) =57% Unfavorable (GOS 1-3) =43% *Middle-aged group 40-64yr* Favorable (GOS 4-5) =47% Unfavorable (GOS 1-3) =53% *Elderly group 65+yr* Favorable (GOS 4-5) =20% Unfavorable (GOS 1-3) =80%
Merzo et al. (2016) Sweden Cohort N=284	Median GCS=5 (IQR 5-6)	*Elderly group* (n=62) Mean Age=73yr Male=65%, Female=35% *Younger group* (n=222) Mean Age=39yr Male=84%, Female=16%	At 6mo: *Elderly Group* Favorable (GOSE)=72% *Young Group* Favorable (GOSE)=51%

Author Year Country Study Design Sample Size	Injury Severity	Age and Sex	Functional Outcomes Findings
You et al. (2016) China Cohort N=166	GCS 6-8=70% GCS 3-5=30%	*ICP monitoring* (n=80) Median Age=74yr (IQR 68-78) Male=54%, Female=46% *Non-ICP monitoring* (n=86) Median Age=76yr (IQR 69-82) Male=48%, Female=52%.	At 6mo: *ICP Monitoring* Mean GOS=3.0 *Non-ICP Monitoring* Mean GOS=2.5
Yokobori et al. (2016) Japan Cohort N=1165	Severe TBI	*1998 Cohort* (n=306) Mean Age=75.3yr Male=64%, Female=36% *2004 Cohort* (n=380) Mean Age=76.0yr Male=60%, Female=40% *2009 Cohort* (n=479) Mean Age=77.1yr Male=59%, Female=41%	*1998 Cohort* GOS 1=62.7% GOS 2=8.5% GOS 3=15.0% GOS 4=6.5% GOS 5=7.2% *2004 Cohort* GOS 1=47.9% GOS 2=12.6% GOS 3=22.4% GOS 4=11.1% GOS 5=6.1% *2009 Cohort* GOS 1=51.1% GOS 2=12.4% GOS 3=20.7% GOS 4=9.8% GOS 5=5.6%
Anke et al. (2015) Norway Cohort N=163	Mean AIS head=4.3 Mean Lowest GCS=5.7	Mean Age=40.1yr Male=78%, Female=22% *Age group 16-39yr* (n=89) *Age Group 40-64yr* (n=56) *Age Group ≥65yr* (n=18)	At 3mo GOSE 2=3% GOSE 3=17% GOSE 4=7% GOSE 5=39% GOSE 6=19% GOSE 7=7% GOSE 8=8% *At 12mo* GOSE 2=2% GOSE 3=9% GOSE 4=4% GOSE 5=18% GOSE 6=31% GOSE 7=14% GOSE 8=22%
Suehiro et al. (2014) Japan Cohort N=401	Severe TBI GCS <7	*Intensive Normothermia* (n=129) Mean Age=53.6yr Male=67.9%, Female=32.1% *Hypothermia* (n=47) Mean Age=46.9yr	*Hypothermia* Favorable (GOS 4-5) =52.4% *Normothermia* Favorable (GOS 4-5) =26.9%

Author Year Country Study Design Sample Size	Injury Severity	Age and Sex	Functional Outcomes Findings
		Male=100%, Female=0% *No temperature management* (n=225) Mean Age=61.5yr Male=70%, Female=30%	*No temperature management* Favorable (GOS 4-5) =20.7%
Walder et al., (2013) Switzerland Cohort N=921	Median GCS=9 (IQR 4-14)	*Younger adults <65yr* (n=601) Mean Age= 55yr Male=71.2% *Older adults ≥65yr* (n=320) Mean Age=76.5yr Male=61.6%	*Survivors* At 3mo: Median GOSE=5 (IQR 3-7) At 6mo: Median GOSE=6 (IQR 4-8)
Taussky et al. (2012) Case Series Switzerland N=37	Median initial GCS=8	Median Age=73yr (IQR 10yr) Male=46%, Female=54%	At discharge: GOS 4-5=41% GOS 3=22% GOS 1-2=38%
De Bonis et al. (2011) Cohort Italy N=44	Mean GCS=6.7	Mean Age=76.6yr Male=59%, Female=41%	At discharge: GOS 1-3=82%
Brazinova et al. (2010) Austria Case Series N=100	GCS 3=71% GCS 4=29%	*Age ≥66yr* Male=71%, Female=29%	At 12mo: Favorable (GOS 4-5) =11% Unfavorable (GOS 1-3) =89%
Utomo et al. (2009) The Netherlands Case Series N=428	AIS 4=58.6% AIS 5=41.4%	Age >64yr Male=54.67%, Female=45.32%	At 6mo: GOSE 1=7.5% GOSE 2=0.5% GOSE 3=37% GOSE 4=12.5% GOSE 5=4.5% GOSE 6=6.5% GOSE 7=15.5% GOSE 8=16%
Mohindra et al., (2008) India Cohort N=1071	GCS 3-8=32 GCS 9-12=2 GCS 13-15=11	*Older adult Group* (>70yr) (n=45) Mean Age=72.4yr Male=76%, Female=24% *Young Group* (20-40yr) (n=1026) Mean Age=Not Reported Gender: Not Reported	*Older adult Group* (>70yr) *GCS 13-15* GOS 4=80% *GCS 9-12* GOS 1=71.4% *Younger Group* Favorable outcome=62.8%
Yap & Chua (2008) Singapore Case Series	Mild=42.9% Moderate=26.5% Severe=28.6% Very Severe=1%	Mean Age=68.3yr Male=71%, Female=29%	At Discharge: GOS 1=1.9% GOS 2=1.9% GOS 3=92.3% GOS 4=3.8%

Author Year Country Study Design Sample Size	Injury Severity	Age and Sex	Functional Outcomes Findings
N=52			GOS 5=0% At 6mo: GOS 1=3.8% GOS 2=1.9% GOS 3=63.5% GOS 4=17.3% GOS 5=3.8%
Tokutomi et al. (2008) Japan Cohort N=797	*6-39yr* Mean GCS=6.0 *40-69yr* Mean GCS=5.7 *≥70yr* Mean GCS=6.1	*Age 6-39yr* (n=302). Male=82.1% *Age 40-69yr* (n=306). Male=76.8% *Age ≥70yr* (n=189). Male=61.3%	At discharge: *Age 40-69yr* GOS 5=10.1% GOS 4=13.7% GOS 3=12.4% GOS 2=10.8% GOS 1=52.9% *Age ≥70yr* GOS 5=5.3% GOS 4=4.8% GOS 3=11.6% GOS 2=9.0% GOS 1=69.3%
Lee et al. (2006) Singapore Case Series N=528	GCS= <8	Mean Age=44.6yr Male=80%, Female=20% *0-20yr*=8.3% *21-40yr*=41.4% *41-60yr*=26% *>61yr*=24.6%	At 6mo: GOS 1=36.7% *Unfavorable Outcome* GOS 2=51.5% GOS 3=48.5% *Favorable Outcome* GOS 4=18.5% GOS 5=81.5%
Gan et al., (2004) Singapore Cohort N=324	*Older adults* Mean GCS=8.3 *Younger adults* Mean GCS=8.59	*Younger adults (20-40yr)* (n=148) Mean Age=29.22yr Male=87%, Female=13% *Older adults (≥64yr)* (n=65) Mean Age=73.86yr Male=58%, Female= 42%	*Younger adults* (20-40yr) GOS 1=20.9% GOS 2=14.2% GOS 3=64.9% *Older adults* (≥64yr) GOS 1=55.4% GOS 2=21.5% GOS 3=23.1%
Ushewokunze et al. (2004) UK Case Series N=71	Severe TBI GCS= <8	Mean Age=77yr Male=49.3%, Female=50.7%	At 6mo: GOS 1=80% GOS 2=3% GOS 3=16% GOS 4=1% GOS 5=0%
Mosenthal et al. (2002)	AIS head ≥3 ≤64yr	*Age ≤64yr* (n=539) Male=60%, Female=40%	*Survivors* GOS 4 or 5= 93%

Author Year Country Study Design Sample Size	Injury Severity	Age and Sex	Functional Outcomes Findings
United States Cohort N=694	GCS=10.2 > 64yr GCS=10.5	*Age > 64yr* (n=155) Male=80%, Female=20%	GOS 2 or 3= 7%
Gomez et al. (2000) Spain Case Series N=797	GCS ≤8	Male=78%, Female=22% *Age 15-25yr (n=327)* *Age 26-35yr (n=154)* *Age 36-45yr (n=102)* *Age 46-55yr (n=72)* *Age 56-65yr (n=66)* *Age >65yr (n=76)*	*46-55yr* GOS 1=37.5% GOS 2=2.8% GOS 3=27.8% GOS 4=20.8% GOS 5=11.1% *55-65yr* GOS 1=65.2% GOS 2=3.0% GOS 3=16.7% GOS 4=7.6% GOS 5=7.6% *>65yr* GOS 1=86.8% GOS 2=1.3% GOS 3=3.9% GOS 4=1.3% GOS 5=6.6%
Pennings et al. (1993) USA Cohort N=92	Elderly GCS=3.5 Young GCS=3.6	*Elderly* (n=42) Mean Age=74yr Male-Female ratio 2:1 *Young* (n=50) Mean Age= 28yr Male-Female ratio 4:1	At discharge: *Elderly Group* GOS 1=79% GOS 2=14% GOS 3=5% GOS 4=2% GOS 5=0% *Young Group* GOS 1=36% GOS 2=8% GOS 3=18% GOS 4=16% GOS 5=22%
Ross et al. (1992) USA Cohort N=195	GCS 3-8=48.7% GCS 9-12=21.5%	Mean Age=75.5yr Male=67%, Female=33%	At 6mo: GOS 1=75% GOS 2=1% GOS 3=10% GOS 4=4% GOS 5=9% Lost to follow-up=2%
Kotwika & Jakubowski (1992) Poland Case Series	GCS 3-5=24 GCS 6-8=29 GCS 9-12=53 GCS 13-15=30	*Age >70yr* Male=65%, Female=35%	GOS 1=25 GOS 2=16 GOS 3-20 GOS 4=4

Author Year Country Study Design Sample Size	Injury Severity	Age and Sex	Functional Outcomes Findings
N=136			GOS 5=71
Vollmer et al. (1991) USA Case Series N=661	*46-55yr* GCS 3-8=93.3% GCS 9-15=6.7% *≥56yr* GCS 3-8=90% GCS 9-15=10%	Sex=Not Reported *Age 16-26yr (n=311)* *Age 26-35yr (n=151)* *Age 36-45yr (n=83)* *Age 46-55yr (n=45)* *Age ≥56 (n=71)*	*Age 46-55yr* GOS 1=48.9% GOS 2=8.9% GOS 3=20.0% GOS 4=11.1% GOS 5=11.1% *Age ≥56yr* GOS 1=80.3% GOS 2=2.8% GOS 3=8.5% GOS 4=8.5% GOS 5=0.0%

*GOS=Glasgow Outcome Scale, GOSE=Glasgow Outcome Scale Extended, ICP=Intracranial Pressure, GCS=Glasgow Coma Scale, AIS=Abbreviated Injury Score

Discussion

Though older adults with TBI may initially have lower GOS scores at discharge, with unfavorable recovery (GOS=3) seen in 87%, scores often improve in the months post discharge, especially when individuals are discharged to rehabilitation facilities or nursing homes (Akbik et al., 2019; Van Wessem & Leenen, 2020; Yap & Chua et al., 2008). Thus, lower GOS scores do not necessarily predict long-term poor outcome for patients. Further, despite younger cohorts having significantly higher GOS scores than older cohorts, functional gains with respect to cognition, balance and activity of daily living were found to be similar for both older and younger age cohorts (Gross & Amsler, 2018; Kim et al., 2019). Those with GOS scores of 4 and greater demonstrated significantly higher rates of recovery (Anke et al., 2015; Taussky et al., 2012; Walder et al., 2013).

While very few older adults achieved good recovery (GOS=5) across all studies, favourable outcomes were found for older age adults who underwent intracranial pressure (ICP) monitoring, as well as for those with evacuated mass lesions who were exposed to hypothermic conditions (Suehiro et al., 2014; You et al., 2016). Of the studies that compared older age cohorts to younger cohorts, some suggested that regardless of initial injury severity, increased age may be a significant predictor for increased mortality as well as poor outcomes following intensive treatments (De Bonis et al., 2011; Erlebach et al; 2017; Merzo et al., 2016; Mohindra et al., 2008; Pennings et al., 1993; Ross et al., 1992; Ushewokunze et al., 2004).

Conclusion

There is level 2 evidence that, while GOS scores at discharge are lower in older adults than in younger adults, scores may improve post-discharge, in association with functional gains in cognition, balance and activities of daily living.

KEY POINTS

- Older adults may experience poor recovery outcomes and low Glasgow Outcome Scale (GOS) scores when compared to their younger counterparts; however, GOS scores may improve post discharge.

Functional Independence Measure

The Functional Independence Measure (FIM) (Granger et al., 1986), is an 18-item ordinal scale that measures functional status, with lower scores indicating a higher need for assistance, and higher scores indicating independence and lower scores indicating dependence (van Baalen et al., 2003). The FIM is frequently used in rehabilitation to measure multiple domains, including self-care, communication and social cognition, among others (Shukla et al., 2011). The FIM includes 18 items with a minimum score of 1 ('complete dependence') and a maximum score of 7 ('complete independence'), and a total score range of 18 to 126 (Ottenbacher et al., 1996). Table 13 presents findings on the FIM in older adults with moderate to severe TBI.

TABLE 13 | Functional Independence Measure in Older Adults post TBI

Author Year Country Study Design Sample Size	Injury Severity	Age and Sex	Discharge Disposition Findings
Harada et al. (2021) Japan Cohort N=63	Mean GCS=8.9	Male=83.3%, Female=12.7% *Age ≤24yr* (n=14) *Age 25-44yr* (n=15) *Age 45-64yr* (n=15) *Age ≥65* (n=19)	*Age ≤24yr* At Discharge: Mean Cognitive FIM=29.1 Mean Motor FIM=86.8 *Age 25-44yr* At Discharge: Mean Cognitive FIM=30.6 Mean Motor FIM=88.5 *Age 45-64yr* At Discharge: Mean Cognitive FIM=29.3 Mean Motor FIM=85.3 *Age ≥65 Group* At Discharge: Mean Cognitive FIM=23.3 Mean Motor FIM=60.7
Fawcett et al., (2015) USA Cohort	AIS ≤3=12,767 AIS >3=1,769 ISS >9=65.89%	Male=42%, Female=58% *Age 55-64yr* (n=3,821) *Age 65-74yr* (n=2,946)	Overall FIM At Discharge: FIM 11-12=48.3% FIM 8-10=33.1%

Author Year Country Study Design Sample Size	Injury Severity	Age and Sex	Discharge Disposition Findings
N=14,536		*Age 75-84yr* (n=3,787) *Age ≥85yr* (n=3,981)	FIM 3-7=7.6% Missing=10.9%
Pedersen et al., (2015) Denmark Cohort N=411	*Age group 18-39yr* Mean GCS=6 *Age group 40-64yr* Mean GCS=7 *Age group 65+* Mean GCS=11	*Age group 18-39yr* (n=204) Mean Age=27yr Male=81%, Female=19% *Age group 40-64yr* (n=152) Mean Age=52yr Male=77%, Female=23% *Age group ≥65yr* (n=55) Mean Age=69yr Male=71%, Female=29%	*Age group 18-39yr* Mean FIM Admission=48 Mean FIM Discharge=85 *Age group 40-64yr* Mean FIM Admission=49 Mean FIM Discharge=80 *Age group ≥65yr* Mean FIM Admission=48 Mean FIM Discharge=76
Hirshon et al., (2013) USA Cohort N=60	Moderate to Severe TBI	*Deceased* (n=30) Mean Age=78yr Male=53%, Female=47% *Living* (n=30) Mean Age=77.1yr Male=53%, Female=47%	At Discharge: *Deceased* Mean FIM=85.9 *Living* Mean FIM=75.7
Ramanathan et al. (2012) USA Cohort N=2090	*Younger elderly* Mean GCS=5.3 *Middle Elderly* Mean GCS score=5.4 *Older Elderly* Mean GCS score=6.1	Male=57%, Female=43% *Younger Elderly 65-73yr* (n=1079) Mean Age=69.1yr *Middle Elderly 74-82yr* (n=1348) Mean Age= 78yr *Older Elderly 83-90yr* (n=799) Mean Age=85.8yr	At Discharge *Young Elderly*=12.3 *Middle Elderly*=9.9 *Older Elderly*=7.7
Frankel et al. (2006) USA Cohort N=534	Mean GCS=11	*Younger patients* (n=267) Mean Age=30.2yr Male=74.5%, Female=25.5% *Older patients* (n=267) Mean Age=66.6yr Male=68.9%, Female=31.1%	*Younger patients* FIM at Admission=64.4 FIM at Discharge101.5 *Older Patients* FIM at Admission=53.6 FIM at Discharge=87.8
Susman et al. (2002) USA Cohort N=11,722	GCS=12.15 ISS=17.52	*Older Adults* (n=3,203) Mean Age=78.3yr Male=50.4%, Female=49.5% *Younger Adults* (N=8,569) Mean Age=34.8yr Male=65%, Female=35%	% of Abnormal FIM *Older Adults* FIM Expression=16.9% FIM Feeding=33.6% FIM Locomotion=35.8% *Young Adults* FIM Expression=8.0% FIM Feeding=17.9% FIM Locomotion=18.3%

Author Year Country Study Design Sample Size	Injury Severity	Age and Sex	Discharge Disposition Findings
Cifu et al. (1996) USA Cohort N=100	Mean GCS=10	*Older adults* (n=50) Mean Age=66.8yr Male=70%, Female=30% *Young* (n=50) Mean Age=32.7yr Male=70%, Female=30%	Mean FIM *Older adults* (n=50) FIM at Admission=52.18 FIM at Discharge=90.60 *Young* (n=50) FIM at Admission=66.15 FIM at Discharge=99.42

*GCS=Glasgow Coma Scale, FIM-Functional Independence Measure

Discussion

While recovery in older adults post-TBI does occur, the process is slower (Frankel et al., 2006). Studies that examined FIM scores at admission and at discharge in older adults and younger individuals, reported that older adults showed lower scores when compared to their younger counterparts (Cifu et al., 1996; Frankel et al., 2006; Susman et al., 2002). However, when specifically assessing cognitive and motor FIM scores, no significant differences were found across age groups (<40 years, <65 years, >65 years) at discharge and after rehabilitation, indicating that older adults, much like their younger counterparts, can indeed be rehabilitated successfully (Harada et al., 2012; Hirshon et al., 2013 Pederson et al., 2015). Positive gains on the FIM can be negatively impacted by medication as well as the presence of existing comorbidities (Cifu et al., 1996; Harada et al., 2021); for instance, the use of anti-psychotic drugs may lead to unfavorable scores (Harada et al., 2021).

Conclusion

There is level 2 evidence that older adults may attain similar functional gains when compared to younger cohorts, as assessed by the FIM.

KEY POINTS

- While the recovery of older adults with TBI may be slower than younger adults, they may attain functional gains as measured by the Functional Independence Measure (FIM) from admission to discharge with similar recovery of function.

Rehabilitation

Rehabilitation for older adults group needs to take into account their unique cognitive and physical needs (Mas et al., 2017). Rehabilitation is critical to ensure the optimization of long-term outcomes in of older adults with moderate to severe TBI; however, difficulties associated with age-related factors such as polypharmacy and slower rates of recovery may result in additional complexities (Noël et al., 2023). Rehabilitation post-TBI often involves reintegration to the community, as well as across the social, emotional and vocational domains (Chua et al., 2007). For older adults, addressing the social aspect of rehabilitation is critical to prevent loneliness, which is often associated with lower cognitive function, as well as biological mechanisms involving increased cortisol and inflammation (Boss et al., 2015).

Community Reintegration

Community reintegration is a dynamic and multidimensional process, and it is considered the main goal of rehabilitation (Ritchie et al., 2014). Age may influence functional outcomes and quality of life post TBI, with younger individuals showing better cognitive outcomes and recovery than older individuals (Mohamed Ludin & Abdul Rashid, 2020). Older adults who have sustained a TBI often experience challenges when reintegrating into their communities, including lower quality of life, changes in pre-injury roles, and an inability to return to work (Dainter et al., 2019). Higher social participation and quality of life in individuals with TBI have been associated with factors such as opportunities for participation in activities with others, mental health (e.g., depression), cognitive and physical impairments and the environment (McLean et al., 2014). Table 14 presents findings related to the community reintegration of older adults with moderate to severe TBI.

TABLE 14 | Community Reintegration Outcomes in Older Adults post TBI

Author Year Country Study Design Sample Size	Methods	Outcome
Niemeier et al. (2021) USA Cohort N=5,109	**Population:** TBI; Male=67.3%, Female=32.7%; *Age 65-74yr* (n=1882), Mean Age=68.3yr; *Age 75-84yr* (n=1773), Mean Age=78.1y; *Age ≥85yr* (n=1454), Mean Age=92.4yr; Mean Age at Injury=67.2yr; Mean Time Post Injury=Not Reported. **Intervention:** Retrospective cohort of older adults that underwent inpatient rehabilitation to examine post TBI perceived life satisfaction and participation outcomes. Participants had completed follow-up at 1, 2, 5 or 10yr. **Outcome Measures:** Satisfaction with Life Scale (SWLS), and Participation Assessment with Recombined Tools-Objective (PART-O).	1. At year one, compared to the 65-74yr group, SWLS was significantly higher in other 2 older age groups (≥75yr) (p<.001), indicating higher levels of satisfaction with life. 2. The ≥85yr cohort experienced significantly greater declines in participation scores, as measured by the PART-O. 3. Significant positive correlations were found between SWLS total score and PART-O total score in the entire sample and within each of the three age cohorts (all p < .001), suggesting strong positive relationships between participation and life satisfaction.
Gross & Amsler (2018) Switzerland	**Population:** TBI; *Group <65yr* (n=216); Mean Age=43.24yr; Male=67.6%, Female=32.4%; Mean GCS=11.83; *Group ≥65yr* (n=110); Mean Age=73.56yr;	1. The cognitive domain of the QOLIBRI showed a trend towards a lower outcome in older adults (p=.086).

Author Year Country Study Design Sample Size	Methods	Outcome
Cohort N=326	Male=66.4%, Female=33.6%; Mean GCS= 12.91; Mean Age at Injury=53.47yr; Mean Time Post Injury=Not Reported. **Intervention:** Prospective cohort of the differences in functional or health-related quality of life outcomes between older (>65yr) and younger adults (16-64yr) with TBI who attended rehabilitation immediately after the initial hospital treatment. Outcome measures were assessed at 1yr. **Outcome Measures:** Quality of Life after Brain Injury (QOLIBRI), Euro Quality of Life Group Health-related Quality of Life on five dimensions (EQ-5D), Short Form-36 (SF-36), Trauma Outcome Profile (TOP), Glasgow Outcome Scale (GOS).	2. In the SF-36, the two physically oriented sub-scores showed significantly lower values in the older group (p=.029, p=.014). 3. There were no differences between younger versus older patients in overall functional or health-related QoL scores including the EQ-5D, the GOS and the TOP after 1 year. 4. There was no correlation between the total QOLIBRI age age (Pearson r=−0.09) or trauma severity (AIS) of the head (r=−0.05). 5. Outcome scores at 1yr on the total QOLIBRI were associated with age 80+ (p=.029), but not with overall age (p=.218).
Anke et al. (2015) Norway Cohort N=163	**Population:** Severe TBI; Total Mean Age=40.1yr; Gender: Male=78%; Female=22%; *Age Group 16-39yr* (n=89); *Age Group 40-64yr* (n=56); *Age Group ≥65yr* (n=18); Mean GCS=5.7; Mean AIS head score=4.3; Mean Time Post Injury=Not Reported. **Intervention:** Prospective cohort of individuals (>16yr) with severe TBI, to examine the impact of demographic and acute injury-related variables on life satisfaction and functional recovery. Outcome measures were assessed at 3mo and 12mo. **Outcome Measures:** Glasgow Outcome Scale Extended (GOSE), Rivermead Post-concussion Symptoms Questionnaire (RPQ), Hospital Anxiety and Depression Scale (HADS), and self-reported satisfaction with life, Mortality, Discharge destination.	1. At 12 months postinjury, 63% of 147 available participants were satisfied with their life situation. 2. The significant explanatory variables in the final model of satisfaction with life were age (>65 years) and lower education (<13 years), as well as higher GOSE score, lower RPQs core, and no depression at 12 months postinjury.
Testa et al. (2005) USA Cohort N=277	**Population:** TBI (N=195); *TBI younger patients* (n=146); Mean Age=29.1yr; Male= 62%: Female=38%; Mean GCS = 11.3; *TBI older patients* (n=49); Mean Age=65.8yr; Male= 62%, Female=38%; Mean GCS = 12.5; *Orthopedic injury younger patients* (n=54); Mean Age=31.1yr; Male= 69%, Female=31%. *Orthopedic injury older patients* (n=28); Mean Age=64.2yr; Male= 61%, Female=39%. Mean Time Post Injury=Not Reported. **Intervention:** Longitudinal cohort study of individuals with TBI to examine age and functional outcome differences compared with orthopedic patients. **Outcome Measures:** Disability rating scale (DRS), Mayo-Portland adaptability Inventory (MPAI) version 2.3, Independent Living scale (ILS), Vocational	1. For the ILS-LT, significant main effects for group (p=.025) and age (p=.007) were found with older patients and those with TBIs more likely to be dependent on others postinjury. 2. For the VISLT, there were significant main effects for group (p<.001) and age (p=.005). There was a significant age by group interaction (p=.048). Older TBI patients had the lowest VIS-LT mean score, indicating that they were more likely to be unemployed or retired.

Author Year Country Study Design Sample Size	Methods	Outcome
	Independence Scale (VIS), Injury Severity Scale (ISS), Galveston Orientation and Amnesia Test (GOAT).	

Discussion

Four studies examined aspects of community reintegration, including life satisfaction, quality of life, independence, and social participation. When comparing three different cohorts of older adults, Niemeier et al. (2021) found that life satisfaction post-TBI increased across all age groups; however, the young-old subgroup (65-74 years) had the poorest life satisfaction outcomes. The authors also reported that social participation decreased across all three groups, with the oldest group (≥85 years) showing lower scores (Niemeier et al., 2021). Similar results were reported by Anke et al. (2015), who found that increased age and better functional outcomes were positive related to life satisfaction. In a prospective cohort, Gross et al. (2018) found comparable quality of life outcomes at 1 year for younger and older adults who had sustained a TBI. After controlling for age over 80 years, the authors found that overall age did not have any additional significant influence on quality of life, as measured by the QOLIBRI at 1 year (Gross & Amsler, 2018). Testa et al. (2005) compared outcomes for individuals with TBI and those with orthopedic injury to examine the effects of aging on recovery. Regarding independence, the authors found significant main effects for group and age in the independent living scale (ILS), with older patients and those with TBIs being more likely to be dependent on others post injury. Older individuals with TBI also presented with the lowest score on the Vocational Independence Scale (VIS), indicating that older persons were more likely to be retired or unemployed (Testa et al., 2005).

Conclusion

There is level 2 evidence (Anke et al., 2015; Niemeier et al., 2021) that, while life satisfaction may increase with age, social participation declines, with the lowest scores shown in individuals 85 years of age and older.

There is level 2 evidence (Gross & Amsler, 2018) that older and younger adults may present with comparable quality of life outcomes up to age 80, with a slight decrease thereafter.

There is level 2 evidence (Testa et al., 2005) that older individuals with moderate to severe TBI may be less likely to be independent, when compared to younger individuals.

KEY POINTS

- Life satisfaction post moderate to severe TBI may increase with age; however, social participation, quality of life and independence may decline, particularly in those 80 years and older.

Cognition

Older adults with moderate to severe TBI may present with injury-related sequelae that may interact with the normal aging process, affecting areas of functioning such as mobility, communication, participation and cognition (Rabinowitz et al., 2021). The combination of age-related cognitive decline and neurological damage sustained post-TBI has a cumulative effect and produces more profound deficits in older adults. For instance, Alzheimer's disease (AD) is the most common cause of dementia in older adults; for those who have sustained a TBI, the risk of dementia may increase approximately 1.5 times (Gu et al., 2022). This relationship between TBI and AD has been reported in moderate to severe injuries, with worse injuries associated with AD and other types of dementia; in addition, increased risk of dementia has also been reported for individuals with history of repetitive mild TBI, mostly as a result of participation in sports or miliary occupations (Mendez, 2017). However, findings related to risk of dementia and TBI should be interpreted with caution, and methodological challenges should be taking into account, particularly in retrospective studies (LoBue et al., 2019). Table 15 presents findings related to the cognition in older adults with moderate to severe TBI.

TABLE 15 | Cognition in Older Adults post TBI

Author Year Country Study Design Sample Size	Methods	Outcome
Cifu et al. (1996) USA Cohort N=100	**Population:** *Older adults* (>55yr) (n=50); Mean Age=66.8yr; Male=70%, Female=30%; *Younger adults* (18-54yr) (n=50); Mean Age=32.7yr; Male=70%, Female=30%; Mean GCS=10.1; Time Post-Injury=Not Reported. **Intervention:** Prospective cohort of older adults 55 years and older and a matched cohort of younger adults 18 to 54 years old selected from a national database of inpatient rehabilitation patients to examine differences in functional independence, cognition, and disability status. **Outcome Measures:** Ranchos Los Amigos Scale (RLAS), Length of PTA, Length of stay (LOS), hospital charges, Functional Independence Measure (FIM), Disability Rating Scale (DRS).	1. For the DRS and RLAS, the status of younger persons was significantly better than that for older persons. 2. For the DRS and RLAS the change rate for younger persons was approximately two times greater.
Davis & Acton (1988) USA Cohort N=62	**Population:** Severe TBI; *Older adults* (>50yr) (n=26); Mean Age=65yr; Gender: Not Reported; *Younger adults* (<25yr) (n=26); Mean Age=21yr; Sex=Not Reported; Time Post-Injury=Not Reported. **Intervention:** Retrospective cohort of individuals with TBI 55yr and over admitted to hospital from 1980 to	1. There was a significant difference in RLA cognitive scores at admission and at discharge (p<.01) between the two groups. However, no significant difference was noted in the changes in RLA scores associated with group characteristics.

Author Year Country Study Design Sample Size	Methods	Outcome
	1984 to examine long-term outcome and age differences. **Outcome Measures:** Ranchos Los Amigos Scale (RLAS), Hospital Length of Stay (LOS), Discharge disposition.	2. The younger group, with similar injury severity, achieved a higher cognitive level.

Discussion

Cifu et al. (1996) compared cohorts of older and younger adults, and found that older adults had worse cognitive outcomes that their younger counterparts. Similarly, Davis and Acton (1988) found that younger individuals with a similar injury severity had higher cognitive achievements than older individuals, as measured by the Ranchos Los Amigos Scale (RLAS). Healthy aging involves a decline in cognitive function, such as attention, memory and executive function; however, those with a moderate to severe TBI often present with additional difficulties across cognitive domains (Mattingly & Roth, 2022). More research in older adults with moderate to severe injuries is needed to understand and differentiate the patterns of cognitive decline that occur as a result of TBI, from those associated with the normal aging process.

Conclusion

There is level 2 evidence (Cifu et al., 1996; Davis & Acton, 1988) that older adults with moderate to severe TBI may present with lower cognitive scores that their younger counterparts.

KEY POINTS

- Cognitive scores many be lower in older individuals with moderate to severe TBI, when compared with younger adults.

Mental Health

Post TBI, chronic inflammation and molecular changes may result in reduced cognitive reserve in the brain, leading to increased susceptibility to neurological disease and the development of psychiatric disorders with advancing age (Young et al., 2016). Mental health issues post-TBI may occur across all injury severities and can negatively impact the quality of life and daily function of individuals, affecting domains such as emotion and behavior (Howlett et al., 2022). Individuals who have sustained a TBI may experience a range of symptoms, including depression, anxiety, and suicidal behavior that often result in poor quality of life for individuals and their families (Chan et al., 2009). Older adults present with a higher prevalence of mental health issues, resulting in increased disability, social isolation, high suicide rates and several physical health problems including heart disease and stroke (Thapa et al., 2020).

Considering that the prevalence of mood disorders such as depression is high among older adults in the community and in long-term care, the prevalence among those who have sustained a TBI is even higher, particularly among those who present with comorbid medical conditions (Kim et al., 2017). Table 16 presents findings related to the mental health outcomes in older adults with moderate to severe TBI.

TABLE 16 | Mental Health Outcomes in Older Adults post TBI

Author Year Country Study Design Sample Size	Methods	Outcome
Anke et al. (2015) Norway Cohort N=163	**Population:** Severe TBI; Total Mean Age=40.1yr; Gender: Male=127; Female=36; *Age group 16-39yr* (n=89); *Age Group 40-64yr* (n=56); *Age Group ≥65yr* (n=18); Mean AIS head score=4.3; Mean Time Post Injury=Not Reported. **Intervention:** Prospective cohort of individuals with severe TBI, to examine the impact of demographic and acute injury-related variables on life satisfaction and functional recovery. Outcome measures were assessed at 3mo and 12mo. **Outcome Measures:** Glasgow Outcome Scale Extended (GOSE), Rivermead Post-concussion Symptoms Questionnaire (RPQ), Hospital Anxiety and Depression Scale (HADS), and self-reported satisfaction with life, Mortality, Discharge destination.	1. At 12 months, the absence of functional recovery was related to higher scores (≥8) for anxiety (37% versus 14%) (p= .006) and depression (37% versus 11%) (p =.001), as measured by the HADS, relative to those who recovered. 2. Among those satisfied with life, 94% were 65 years old and older, 38% presented with a possible case of anxiety, and 21% with a possible case of depression (HADS ≥8).

Discussion

In a prospective cohort study, Anke et al. (2015) found that the emotional state at 12 months was related to functional recovery and life satisfaction in those with severe TBI. Those who reported to be satisfied with life were mostly 65 years and older (94%) and presented with lower rates of depression and anxiety than those who were not satisfied (Anke et al., 2015). Further research is needed to examine mental health in older adults with moderate to severe TBI.

Conclusion

There is level 2 evidence (Anke et al., 2015) that individuals who are satisfied with life after severe TBI are more likely to be 65 years and older and more likely to report lower depression and anxiety scores, when compared to those unsatisfied with life. However, further research is needed.

KEY POINTS

- Persons reporting higher life satisfaction post-severe TBI were more likely to report lower depression and anxiety scores over 65 years old; however, further research is needed.

Conclusions

Overall, there is limited research which has specifically examined older adults with a moderate to severe TBI, with the majority of studies addressing mild TBI. Individuals with geriatric trauma are more likely to experience worse outcomes, higher complication rates, and an increased number of pre-existing health conditions, when compared to their younger counterparts (Grossman et al., 2002). Among older adults with TBI, falls are the most common mechanism of injury, with the majority of falls occurring from standing height and being sustained at home (Public Health Agency of Canada, 2020). Older adults with TBI experience high rates of hospitalization, morbidity and mortality, as well as slower recovery rates; further, they do not progress as quickly with rehabilitation as younger patients (Waltzman et al., 2022). While the ultimate goal is to return the patient to pre-morbid functioning, this may not always be possible given the complexities associated with older age that overlap with TBI, including high incidence of comorbidities, cognitive disease processes (e.g., dementia) and natural physical and cognitive declines that can occur with aging (Mattingly & Roth, 2022). While there is a considerable focus on mortality and morbidity in the research literature, it is critical to continue studying recovery, functional outcomes, community reintegration and mental health among older adult survivors with moderate to severe TBI.

References

Akbik, O. S., Starling, R. V., Gahramanov, S., Zhu, Y., & Lewis, J. (2019). Mortality and Functional Outcome in Surgically Evacuated Acute Subdural Hematoma in Elderly Patients. *World neurosurgery, 126*(101528275), e1235-e1241. https://doi.org/https://dx.doi.org/10.1016/j.wneu.2019.02.234

Anke, A., Andelic, N., Skandsen, T., Knoph, R., Ader, T., Manskow, U., Sigurdardottir, S., & Roe, C. (2015). Functional Recovery and Life Satisfaction in the First Year After Severe Traumatic Brain Injury: A Prospective Multicenter Study of a Norwegian National Cohort. *The Journal of head trauma rehabilitation, 30*(4), E38-49. https://doi.org/https://dx.doi.org/10.1097/HTR.0000000000000080

Arac, D. (2022). Age Factor Affecting The Success of Decompressive Cranietomy in Traumatic Brain Injury: Single Center Experience. *International Journal of Academic Medicine and Pharmacy, 4*(1), 19-23. https://doi.org/https://dx.doi.org/10.29228/jamp.52250

Asemota, A. O., George, B. P., Cumpsty-Fowler, C. J., Haider, A. H., & Schneider, E. B. (2013). Race and insurance disparities in discharge to rehabilitation for patients with traumatic brain injury. *Journal of neurotrauma, 30*(24), 2057-2065.

Baggiani, M., Guglielmi, A., & Citerio, G. (2022, Apr 1). Acute traumatic brain injury in frail patients: the next pandemic. *Curr Opin Crit Care, 28*(2), 166-175. https://doi.org/10.1097/mcc.0000000000000915

Bala, M., Willner, D., Klauzni, D., Bdolah-Abram, T., Rivkind, A. I., Gazala, M. A., Elazary, R., & Almogy, G. (2013). Pre-hospital and admission parameters predict in-hospital mortality among patients 60 years and older following severe trauma. *Scandinavian journal of trauma, resuscitation and emergency medicine, 21*(101477511), 91. https://doi.org/https://dx.doi.org/10.1186/1757-7241-21-91

Barrett, J. W., Williams, J., Griggs, J., Skene, S., & Lyon, R. (2022, Jun 7). What are the demographic and clinical differences between those older adults with traumatic brain injury who receive a neurosurgical intervention to those that do not? A systematic literature review with narrative synthesis. *Brain Inj, 36*(7), 841-849. https://doi.org/10.1080/02699052.2022.2093398

Bhullar, I. S., Roberts, E. E., Brown, L., & Lipe, H. (2010). The effect of age on blunt traumatic brain-injured patients. *American Surgeon, 76*(9), 966-968. http://docserver.ingentaconnect.com/deliver/connect/sesc/00031348/v76n9/s30.pdf?expires=

1294768729&id=60634061&titleid=11737&accname=Elsevier+Science&checksum=4154451380 89D89A9877AB2F6B5A6037

Boss, L., Kang, D.-H., & Branson, S. (2015). Loneliness and cognitive function in the older adult: a systematic review. *International psychogeriatrics, 27*(4), 541-553.

Bouras, T., Stranjalis, G., Korfias, S., Andrianakis, I., Pitaridis, M., & Sakas, D. E. (2007). Head injury mortality in a geriatric population: differentiating an "edge" age group with better potential for benefit than older poor-prognosis patients. *Journal of neurotrauma, 24*(8), 1355-1361.

Brazinova, A., Mauritz, W., Leitgeb, J., Wilbacher, I., Majdan, M., Janciak, I., & Rusnak, M. (2010, Sep). Outcomes of patients with severe traumatic brain injury who have Glasgow Coma Scale scores of 3 or 4 and are over 65 years old. *J Neurotrauma, 27*(9), 1549-1555. https://doi.org/10.1089/neu.2010.1315

Brito, A., Costantini, T. W., Berndtson, A. E., Smith, A., Doucet, J. J., & Godat, L. N. (2019, 2019/12/01/). Readmissions After Acute Hospitalization for Traumatic Brain Injury. *Journal of Surgical Research, 244*, 332-337. https://doi.org/https://doi.org/10.1016/j.jss.2019.06.071

Campbell, M. (2000). Rehabilitation for traumatic brain injury : physical therapy practice in context.

Canadian Institute for Health Information. (2006). *Head Injuries in Canada: A decade of change*.

Canadian Institute of Health Information. (2019). *Falls and vehicle collisions top causes of injury hospitalizations for seniors*.

Chan, J., Parmenter, T., & Stancliffe, R. (2009). The impact of traumatic brain injury on the mental health outcomes of individuals and their family carers. *Australian e-Journal for the Advancement of Mental Health, 8*(2), 155-164.

Cherniack, E. P. (2002, Oct). Increasing use of DNR orders in the elderly worldwide: whose choice is it? *J Med Ethics, 28*(5), 303-307. https://doi.org/10.1136/jme.28.5.303

Chico-Fernandez, M., Sanchez-Casado, M., Barea-Mendoza, J. A., Garcia-Saez, I., Ballesteros-Sanz, M. A., Guerrero-Lopez, F., Quintana-Diaz, M., Molina-Diaz, I., Martin-Iglesias, L., Toboso-Casado, J. M., Perez-Barcena, J., & Llompart-Pou, J. A. (2020). Outcomes of very elderly trauma ICU patients. Results from the Spanish trauma ICU registry. *Medicina Intensiva, 44*(4), 210-215. https://doi.org/http://dx.doi.org/10.1016/j.medin.2019.01.006

Chua, K. S., Ng, Y.-S., Yap, S. G., & Bok, C.-W. (2007). A brief review of traumatic brain injury rehabilitation. *Annals-Academy of Medicine Singapore, 36*(1), 31.

Cifu, D. X., Kreutzer, J. S., Marwitz, J. H., Rosenthal, M., Englander, J., & High, W. (1996). Functional outcomes of older adults with traumatic brain injury: a prospective, multicenter analysis. *Archives of physical medicine and rehabilitation, 77*(9), 883-888.

Cusimano, M. D., Saarela, O., Hart, K., Zhang, S., & McFaull, S. R. (2020). A population-based study of fall-related traumatic brain injury identified in older adults in hospital emergency departments. *Neurosurgical focus, 49*(4), E20.

Dainter, K. M., McKinlay, A., & Grace, R. C. (2019). Change in life roles and quality of life for older adults after traumatic brain injury. *Work, 62*(2), 299-307. https://doi.org/10.3233/wor-192864

Dang, Q., Simon, J., Catino, J., Puente, I., Habib, F., Zucker, L., & Bukur, M. (2015). More fateful than fruitful? Intracranial pressure monitoring in elderly patients with traumatic brain injury is associated with worse outcomes. *The Journal of surgical research, 198*(2), 482-488. https://doi.org/https://dx.doi.org/10.1016/j.jss.2015.03.092

Davis, C. S., & Acton, P. (1988). Treatment of the elderly brain-injured patient. Experience in a traumatic brain injury unit. *Journal of the American Geriatrics Society, 36*(3), 225-229.

De Bonis, P., Pompucci, A., Mangiola, A., Paternoster, G., Festa, R., Nucci, C. G., Maviglia, R., Antonelli, M., & Anile, C. (2011). Decompressive craniectomy for elderly patients with traumatic brain injury: it's probably not worth the while. *Journal of neurotrauma, 28*(10), 2043-2048. https://doi.org/https://dx.doi.org/10.1089/neu.2011.1889

de Decker, L., Annweiler, C., Launay, C., Fantino, B., & Beauchet, O. (2014, Mar). Do not resuscitate orders and aging: impact of multimorbidity on the decision-making process. *J Nutr Health Aging, 18*(3), 330-335. https://doi.org/10.1007/s12603-014-0023-5

de Koning, M. E., Spikman, J. M., Coers, A., Schönherr, M. C., & van der Naalt, J. (2015). Pathways of care the first year after moderate and severe traumatic brain injury—Discharge destinations and outpatient follow-up. *Brain injury, 29*(4), 423-429.

Dhandapani, S. S., Manju, D., Sharma, B. S., & Mahapatra, A. K. (2012). Prognostic significance of age in traumatic brain injury. *Journal of Neurosciences in Rural Practice, 3*(2), 131-135. https://doi.org/http://dx.doi.org/10.4103/0976-3147.98208

Dhillon, N. K., Tseng, J., Barmparas, G., Harada, M. Y., Ko, A., Smith, E. J. T., Thomsen, G. M., & Ley, E. J. (2018). Impact of early positive cultures in the elderly with traumatic brain injury. *The Journal of surgical research, 224*(k7b, 0376340), 140-145. https://doi.org/https://dx.doi.org/10.1016/j.jss.2017.11.031

Downey, D. M., Monson, B., Butler, K. L., Fortuna, G. R., Jr., Saxe, J. M., Dolan, J. P., Markert, R. J., & McCarthy, M. C. (2009). Does platelet administration affect mortality in elderly head-injured patients taking antiplatelet medications? *The American surgeon, 75*(11), 1100-1103.

Dziechciaż, M., & Filip, R. (2014). Biological psychological and social determinants of old age: bio-psycho-social aspects of human aging. *Ann Agric Environ Med, 21*(4), 835-838. https://doi.org/10.5604/12321966.1129943

Edlmann, E., & Whitfield, P. C. (2020, Aug). The changing face of neurosurgery for the older person. *J Neurol, 267*(8), 2469-2474. https://doi.org/10.1007/s00415-020-09854-9

Enumah, S., Lilley, E. J., Nitzschke, S., Haider, A. H., Salim, A., & Cooper, Z. (2018). Increased hospice enrollment and decreased neurosurgical interventions without changes in mortality for older Medicare patients with moderate to severe traumatic brain injury. *American journal of surgery, 215*(6), 1016-1019. https://doi.org/https://dx.doi.org/10.1016/j.amjsurg.2018.02.028

Erlebach, R., Pagnamenta, A., Klinzing, S., Stretti, F., Cottini, S., Schupbach, R., Steiger, P., & Brandi, G. (2017). Age-related outcome of patients after traumatic brain injury: a single-center observation. *Minerva anestesiologica, 83*(11), 1169-1177. https://doi.org/https://dx.doi.org/10.23736/S0375-9393.17.11837-7

Fawcett, V. J., Flynn-O'Brien, K. T., Shorter, Z., Davidson, G. H., Bulger, E., Rivara, F. P., & Arbabi, S. (2015). Risk factors for unplanned readmissions in older adult trauma patients in Washington State: a competing risk analysis. *Journal of the American College of Surgeons, 220*(3), 330-338. https://doi.org/https://dx.doi.org/10.1016/j.jamcollsurg.2014.11.012

Florisson, S., Aagesen, E. K., Bertelsen, A. S., Nielsen, L. P., & Rosholm, J. U. (2021, Feb). Are older adults insufficiently included in clinical trials?-An umbrella review. *Basic Clin Pharmacol Toxicol, 128*(2), 213-223. https://doi.org/10.1111/bcpt.13536

Flottemesch, T. J., Raetzman, S., Heslin, K. C., Fingar, K., Coffey, R., Barrett, M., & Moy, E. (2017). Age-related Disparities in Trauma Center Access for Severe Head Injuries Following the Release of the Updated Field Triage Guidelines. *Academic emergency medicine : official journal of the Society for Academic Emergency Medicine, 24*(4), 447-457. https://doi.org/https://dx.doi.org/10.1111/acem.13150

Frankel, J. E., Marwitz, J. H., Cifu, D. X., Kreutzer, J. S., Englander, J., & Rosenthal, M. (2006). A follow-up study of older adults with traumatic brain injury: taking into account decreasing length of stay. *Archives of physical medicine and rehabilitation, 87*(1), 57-62.

Fröhlich, M., Caspers, M., Lefering, R., Driessen, A., Bouillon, B., Maegele, M., & Wafaisade, A. (2020). Do elderly trauma patients receive the required treatment? Epidemiology and outcome of geriatric trauma patients treated at different levels of trauma care. *European Journal of Trauma & Emergency Surgery, 46*(6), 1463-1469. https://doi.org/10.1007/s00068-019-01285-0

Fu, T. S., Jing, R., McFaull, S. R., & Cusimano, M. D. (2015). Recent trends in hospitalization and in-hospital mortality associated with traumatic brain injury in Canada: A nationwide, population-based study. *The journal of trauma and acute care surgery, 79*(3), 449-454.

Fu, W. W., Fu, T. S., Jing, R., McFaull, S. R., & Cusimano, M. D. (2017). Predictors of falls and mortality among elderly adults with traumatic brain injury: A nationwide, population-based study. *PloS one, 12*(4), e0175868. https://doi.org/https://dx.doi.org/10.1371/journal.pone.0175868

Gan, B. K., Lim, J. H. G., & Ng, I. H. B. (2004). Outcome of Moderate and Severe Traumatic Brain Injury amongst the Elderly in Singapore. *Annals of the Academy of Medicine Singapore, 33*(1), 63-67.

Gardner, R. C., Dams-O'Connor, K., Morrissey, M. R., & Manley, G. T. (2018, Apr 1). Geriatric Traumatic Brain Injury: Epidemiology, Outcomes, Knowledge Gaps, and Future Directions. *J Neurotrauma, 35*(7), 889-906. https://doi.org/10.1089/neu.2017.5371

Gómez, P. A., Lobato, R. D., Boto, G. R., De la Lama, A., González, P. J., & de la Cruz, J. (2000). Age and outcome after severe head injury. *Acta Neurochir (Wien), 142*(4), 373-380; discussion 380-371. https://doi.org/10.1007/s007010050445

Gorman, E., Frangos, S., DiMaggio, C., Bukur, M., Klein, M., Pachter, H. L., & Berry, C. (2020). Is trauma center designation associated with disparities in discharge to rehabilitation centers among elderly patients with Traumatic Brain Injury? *American journal of surgery, 219*(4), 587-591. https://doi.org/https://dx.doi.org/10.1016/j.amjsurg.2020.02.026

Grandhi, R., Duane, T. M., Dechert, T., Malhotra, A. K., Aboutanos, M. B., Wolfe, L. G., & Ivatury, R. R. (2008). Anticoagulation and the elderly head trauma patient. *The American surgeon, 74*(9), 802-805.

Granger, C. V., Hamilton, B. B., Keith, R. A., Zielezny, M., & Sherwin, F. S. (1986). Advances in functional assessment for medical rehabilitation. *Topics in Geriatric Rehabilitation, 1*(3), 59-74.

Gross, T., & Amsler, F. (2018). One-year outcome following brain injury: a comparison of younger versus elderly major trauma patients. *Archives of orthopaedic and trauma surgery, 138*(10), 1375-1387. https://doi.org/https://dx.doi.org/10.1007/s00402-018-2974-1

Grossman, M. D., Miller, D., Scaff, D. W., & Arcona, S. (2002). When is an elder old? Effect of preexisting conditions on mortality in geriatric trauma. *Journal of Trauma and Acute Care Surgery, 52*(2), 242-246.

Gu, D., Ou, S., & Liu, G. (2022). Traumatic Brain Injury and Risk of Dementia and Alzheimer's Disease: A Systematic Review and Meta-Analysis. *Neuroepidemiology, 56*(1), 4-16. https://doi.org/10.1159/000520966

Guidet, B., de Lange, D. W., & Flaatten, H. (2018, Nov). Should this elderly patient be admitted to the ICU? *Intensive Care Med, 44*(11), 1926-1928. https://doi.org/10.1007/s00134-018-5054-7

Habicht, D. W., Witham, M. D., & McMurdo, M. E. (2008, Mar). The under-representation of older people in clinical trials: barriers and potential solutions. *J Nutr Health Aging, 12*(3), 194-196. https://doi.org/10.1007/bf02982619

Hammond, F. M., Corrigan, J. D., Ketchum, J. M., Malec, J. F., Dams-O'Connor, K., Hart, T., Novack, T. A., Bogner, J., Dahdah, M. N., & Whiteneck, G. G. (2019, Jul/Aug). Prevalence of Medical and Psychiatric Comorbidities Following Traumatic Brain Injury. *J Head Trauma Rehabil, 34*(4), E1-e10. https://doi.org/10.1097/htr.0000000000000465

Harada, A., Kawai, N., Ogawa, T., Hatakeyama, T., & Tamiya, T. (2021). Long-term Multidisciplinary Rehabilitation Efficacy in Older Patients After Traumatic Brain Injury: Assessed by the Functional Independence Measure. *Acta medica Okayama, 75*(4), 479-486. https://doi.org/https://dx.doi.org/10.18926/AMO/62400

Haring, R. S., Narang, K., Canner, J. K., Asemota, A. O., George, B. P., Selvarajah, S., Haider, A. H., & Schneider, E. B. (2015). Traumatic brain injury in the elderly: morbidity and mortality trends and risk factors. *The Journal of surgical research, 195*(1), 1-9. https://doi.org/https://dx.doi.org/10.1016/j.jss.2015.01.017

Herou, E., Romner, B., & Tomasevic, G. (2015). Acute Traumatic Brain Injury: Mortality in the Elderly. *World neurosurgery, 83*(6), 996-1001. https://doi.org/https://dx.doi.org/10.1016/j.wneu.2015.02.023

Hirshson, C. I., Gordon, W. A., Singh, A., Ambrose, A., Spielman, L., Dams-O'Connor, K., Cantor, J., & Dijkers, M. (2013). Mortality of elderly individuals with TBI in the first 5 years following injury. *NeuroRehabilitation, 32*(2), 225-232. https://doi.org/https://dx.doi.org/10.3233/NRE-130840

Howlett, J. R., Nelson, L. D., & Stein, M. B. (2022, Mar 1). Mental Health Consequences of Traumatic Brain Injury. *Biol Psychiatry, 91*(5), 413-420. https://doi.org/10.1016/j.biopsych.2021.09.024

Karibe, H., Hayashi, T., Narisawa, A., Kameyama, M., Nakagawa, A., & Tominaga, T. (2017, Aug 15). Clinical Characteristics and Outcome in Elderly Patients with Traumatic Brain Injury: For Establishment of Management Strategy. *Neurol Med Chir (Tokyo), 57*(8), 418-425. https://doi.org/10.2176/nmc.st.2017-0058

Kilaru, S., Garb, J., Emhoff, T., Fiallo, V., Simon, B., Swiencicki, T., & Lee, K. F. (1996). Long-term functional status and mortality of elderly patients with severe closed head injuries. *Journal of Trauma - Injury, Infection and Critical Care, 41*(6), 957-963. https://doi.org/http://dx.doi.org/10.1097/00005373-199612000-00003

Kim, D. Y., Kim, M. H., & Pyun, S. B. (2019). Comparison of Functional Outcomes between Elderly and Young Patients with Traumatic Brain Injury in a Subacute Rehabilitation Unit. *Topics in Geriatric Rehabilitation, 35*(2), 141-148. https://doi.org/http://dx.doi.org/10.1097/TGR.0000000000000224

Kim, J. K., Kim, N. Y., & Kim, Y. W. (2017). Predictors for depressive mood in geriatric patients after traumatic brain injury: a retrospective cross-sectional study. *Annals of rehabilitation medicine, 41*(2), 279-289.

Kotwica, Z., & Jakubowski, J. K. (1992). Acute head injuries in the elderly. An analysis of 136 consecutive patients. *Acta Neurochir (Wien), 118*(3-4), 98-102. https://doi.org/10.1007/bf01401293

Krishnamoorthy, V., Distelhorst, J. T., Vavilala, M. S., & Thompson, H. (2015, Jul-Aug). Traumatic Brain Injury in the Elderly: Burden, Risk Factors, and Prevention. *J Trauma Nurs, 22*(4), 204-208; quiz E203-204. https://doi.org/10.1097/jtn.0000000000000135

Kuhne, C. A., Ruchholtz, S., Kaiser, G. M., & Nast-Kolb, D. (2005, Nov). Mortality in severely injured elderly trauma patients--when does age become a risk factor? *World J Surg, 29*(11), 1476-1482. https://doi.org/10.1007/s00268-005-7796-y

Kumar, R. G., Juengst, S. B., Wang, Z., Dams-O'Connor, K., Dikmen, S. S., O'Neil-Pirozzi, T. M., Dahdah, M. N., Hammond, F. M., Felix, E. R., Arenth, P. M., & Wagner, A. K. (2018). Epidemiology of Comorbid Conditions among Adults 50 Years and Older with Traumatic Brain Injury. *Journal of Head Trauma Rehabilitation, 33*(1), 15-24. https://doi.org/http://dx.doi.org/10.1097/HTR.0000000000000273

Kumar, R. G., Olsen, J., Juengst, S. B., Dams-O'Connor, K., O'Neil-Pirozzi, T. M., Hammond, F. M., & Wagner, A. K. (2019). Comorbid Conditions Among Adults 50 Years and Older With Traumatic Brain Injury: Examining Associations With Demographics, Healthcare Utilization, Institutionalization, and 1-Year Outcomes. *The Journal of head trauma rehabilitation, 34*(4), 224-232. https://doi.org/https://dx.doi.org/10.1097/HTR.0000000000000470

Labib, N., Nouh, T., Winocour, S., Deckelbaum, D., Banici, L., Fata, P., Razek, T., & Khwaja, K. (2011). Severely injured geriatric population: morbidity, mortality, and risk factors. *Journal of Trauma, 71*(6), 1908-1914. https://search.ebscohost.com/login.aspx?direct=true&db=cin20&AN=108214166&site=ehost-live

Lee, A. T., Gagnidze, A., Pan, S. R., Sookplung, P., Nair, B., Newman, S.-F., Ben-Ari, A., Zaky, A., Cain, K., Vavilala, M. S., & Rozet, I. (2017). Preoperative Low-Dose Aspirin Exposure and Outcomes After Emergency Neurosurgery for Traumatic Intracranial Hemorrhage in Elderly Patients. *Anesthesia and analgesia, 125*(2), 514-520. https://doi.org/https://dx.doi.org/10.1213/ANE.0000000000002053

Lee, K. K., Seow, W. T., & Ng, I. (2006). Demographical profiles of adult severe traumatic brain injury patients: implications for healthcare planning. *Singapore medical journal, 47*(1), 31-36.

Lee, K. S., Shim, J. J., Yoon, S. M., Oh, J. S., Bae, H. G., & Doh, J. W. (2014). Surgical decision making for the elderly patients in severe head injuries. *Journal of Korean Neurosurgical Society, 55*(4), 195-199. https://doi.org/http://dx.doi.org/10.3340/jkns.2014.55.4.195

Li, C.-Y., Karmarkar, A., Adhikari, D., Ottenbacher, K., & Kuo, Y.-F. (2018). Effects of Age and Sex on Hospital Readmission in Traumatic Brain Injury. *Archives of physical medicine and rehabilitation, 99*(7), 1279-1288.e1271. https://doi.org/https://dx.doi.org/10.1016/j.apmr.2017.12.006

Lilley, E. J., Scott, J. W., Weissman, J. S., Krasnova, A., Salim, A., Haider, A. H., & Cooper, Z. (2018). End-of-Life Care in Older Patients After Serious or Severe Traumatic Brain Injury in Low-Mortality Hospitals Compared With All Other Hospitals. *JAMA surgery, 153*(1), 44-50. https://doi.org/https://dx.doi.org/10.1001/jamasurg.2017.3148

Lilley, E. J., Williams, K. J., Schneider, E. B., Hammouda, K., Salim, A., Haider, A. H., & Cooper, Z. (2016). Intensity of treatment, end-of-life care, and mortality for older patients with severe traumatic brain injury. *The journal of trauma and acute care surgery, 80*(6), 998-1004. https://doi.org/https://dx.doi.org/10.1097/TA.0000000000001028

Livingston, D. H., Lavery, R. F., Mosenthal, A. C., Knudson, M. M., Lee, S., Morabito, D., Manley, G. T., Nathens, A., Jurkovich, G., Hoyt, D. B., & Coimbra, R. (2005, Dec). Recovery at one year following isolated traumatic brain injury: a Western Trauma Association prospective multicenter trial. *J Trauma, 59*(6), 1298-1304; discussion 1304. https://doi.org/10.1097/01.ta.0000196002.03681.18

LoBue, C., Munro, C., Schaffert, J., Didehbani, N., Hart, J., Batjer, H., & Cullum, C. M. (2019). Traumatic Brain Injury and Risk of Long-Term Brain Changes, Accumulation of Pathological Markers, and Developing Dementia: A Review. *J Alzheimers Dis, 70*(3), 629-654. https://doi.org/10.3233/jad-190028

Maiden, M. J., Cameron, P. A., Rosenfeld, J. V., Cooper, D. J., McLellan, S., & Gabbe, B. J. (2020). Long-Term Outcomes after Severe Traumatic Brain Injury in Older Adults. A Registry-based Cohort Study. *American journal of respiratory and critical care medicine, 201*(2), 167-177. https://doi.org/https://dx.doi.org/10.1164/rccm.201903-0673OC

Manivannan, S., Spencer, R., Marei, O., Mayo, I., Elalfy, O., Martin, J., & Zaben, M. (2021). Acute subdural haematoma in the elderly: to operate or not to operate? A systematic review and meta-analysis of outcomes following surgery. *BMJ open, 11*(12), e050786. https://doi.org/https://dx.doi.org/10.1136/bmjopen-2021-050786

Martín-Sánchez, F. J., Brizzi, B. N., González Del Castillo, J., Cantó Blázquez, V., González Jiménez, C., Aguilo Mir, S., Torres Machado, V., Gil, A., Cenjor, R., Miró, O., Jacob Rodríguez, J., Llorens, P., Herrero Puente, P., Fernández Pérez, C., & Lázaro Del Nogal, M. (2018, Oct). Characteristics and outcomes of older adults presented to Spanish emergency departments after a fall. *Eur Geriatr Med, 9*(5), 631-640. https://doi.org/10.1007/s41999-018-0103-x

Mas, M. F., Mathews, A., & Gilbert-Baffoe, E. (2017, Nov). Rehabilitation Needs of the Elder with Traumatic Brain Injury. *Phys Med Rehabil Clin N Am, 28*(4), 829-842. https://doi.org/10.1016/j.pmr.2017.06.014

Mattingly, E., & Roth, C. R. (2022). Traumatic Brain Injury in Older Adults: Epidemiology, Etiology, Rehabilitation, and Outcomes. *Perspectives of the ASHA Special Interest Groups, 7*(4), 1166-1181.

McHugh, D., & Gil, J. (2018, Jan 2). Senescence and aging: Causes, consequences, and therapeutic avenues. *J Cell Biol, 217*(1), 65-77. https://doi.org/10.1083/jcb.201708092

McIntyre, A., Janzen, S., & Teasell, R. (2014). Traumatic Brain Injury in Older Adults: A Review. *Topics in Geriatric Rehabilitation, 30*, 230–236.

McIntyre, A., Mehta, S., Aubut, J., Dijkers, M., & Teasell, R. W. (2013). Mortality among older adults after a traumatic brain injury: a meta-analysis. *Brain injury, 27*(1), 31-40. https://doi.org/https://dx.doi.org/10.3109/02699052.2012.700086

McLean, A. M., Jarus, T., Hubley, A. M., & Jongbloed, L. (2014). Associations between social participation and subjective quality of life for adults with moderate to severe traumatic brain injury. *Disabil Rehabil, 36*(17), 1409-1418. https://doi.org/10.3109/09638288.2013.834986

McMillan, T., Wilson, L., Ponsford, J., Levin, H., Teasdale, G., & Bond, M. (2016). The Glasgow Outcome Scale—40 years of application and refinement. *Nature Reviews Neurology, 12*(8), 477-485.

Meagher, A. D., Beadles, C. A., Doorey, J., & Charles, A. G. (2015). Racial and ethnic disparities in discharge to rehabilitation following traumatic brain injury. *Journal of neurosurgery, 122*(3), 595-601. https://doi.org/https://dx.doi.org/10.3171/2014.10.JNS14187

Mendez, M. F. (2017). What is the Relationship of Traumatic Brain Injury to Dementia? *J Alzheimers Dis, 57*(3), 667-681. https://doi.org/10.3233/jad-161002

Merzo, A., Lenell, S., Nyholm, L., Enblad, P., & Lewen, A. (2016). Promising clinical outcome of elderly with TBI after modern neurointensive care. *Acta neurochirurgica, 158*(1), 125-133. https://doi.org/https://dx.doi.org/10.1007/s00701-015-2639-6

Mitra, B., Cameron, P. A., Gabbe, B. J., Rosenfeld, J. V., & Kavar, B. (2008). Management and hospital outcome of the severely head injured elderly patient. *ANZ journal of surgery, 78*(7), 588-592. https://doi.org/https://dx.doi.org/10.1111/j.1445-2197.2008.04579.x

Miyata, K., Ohnishi, H., Maekawa, K., Mikami, T., Akiyama, Y., Iihoshi, S., Wanibuchi, M., Mikuni, N., Uemura, S., Tanno, K., Narimatsu, E., & Asai, Y. (2016). Therapeutic temperature modulation in severe or moderate traumatic brain injury: a propensity score analysis of data from the Nationwide Japan Neurotrauma Data Bank. *Journal of neurosurgery, 124*(2), 527-537. https://doi.org/https://dx.doi.org/10.3171/2015.3.JNS141895

Mohamed Ludin, S., & Abdul Rashid, N. (2020, Sep). Functional Outcomes and Health-Related Quality of Life After Severe Traumatic Brain Injury: A Review. *Clin Nurs Res, 29*(7), 433-439. https://doi.org/10.1177/1054773818792459

Mohindra, S., Mukherjee, K. K., Gupta, R., & Chhabra, R. (2008). Continuation of poor surgical outcome after elderly brain injury. *Surgical Neurology, 69*(5), 474-477. https://doi.org/http://dx.doi.org/10.1016/j.surneu.2007.02.031

Moseley, A. M., Herbert, R. D., Sherrington, C., & Maher, C. G. (2002). Evidence for physiotherapy practice: a survey of the Physiotherapy Evidence Database (PEDro). *The Australian journal of physiotherapy, 48*(1), 43-49.

Mosenthal, A. C., Lavery, R. F., Addis, M., Kaul, S., Ross, S., Marburger, R., Deitch, E. A., & Livingston, D. H. (2002, May). Isolated traumatic brain injury: age is an independent predictor of mortality and early outcome. *J Trauma, 52*(5), 907-911. https://doi.org/10.1097/00005373-200205000-00015

Mostert, C. Q. B., Singh, R. D., Gerritsen, M., Kompanje, E. J. O., Ribbers, G. M., Peul, W. C., & van Dijck, J. (2022, Mar). Long-term outcome after severe traumatic brain injury: a systematic literature review. *Acta Neurochir (Wien), 164*(3), 599-613. https://doi.org/10.1007/s00701-021-05086-6

Network, T. A. B. I. (2005). *Definition of acquired brain injury*.

Niemeier, J. P., Hammond, F. M., O'Neil-Pirozzi, T. M., Venkatesan, U. M., Bushnik, T., Zhang, Y., & Kennedy, R. E. (2021). Refining understanding of life satisfaction in elderly persons with traumatic brain injury using age-defined cohorts: a TBI model systems study. *Brain injury, 35*(10), 1284-1291. https://doi.org/https://dx.doi.org/10.1080/02699052.2021.1972153

Noël, F., Gagnon, M. P., Lajoie, J., Côté, M., Caron, S. M., Martin, A., Labrie-Pichette, A., & Carvalho, L. P. (2023, Feb 14). Inpatient Physical Therapy in Moderate to Severe Traumatic Brain Injury in in Older Adults: A Scoping Review. *Int J Environ Res Public Health, 20*(4). https://doi.org/10.3390/ijerph20043367

Nott, M. T., Gates, T. M., & Baguley, I. J. (2015, Jun). Age-related trends in late mortality following traumatic brain injury: A multicentre inception cohort study. *Australas J Ageing, 34*(2), E1-6. https://doi.org/10.1111/ajag.12151

Ostermann, R. C., Joestl, J., Tiefenboeck, T. M., Lang, N., Platzer, P., & Hofbauer, M. (2018). Risk factors predicting prognosis and outcome of elderly patients with isolated traumatic brain injury. *Journal of orthopaedic surgery and research, 13*(1), 277. https://doi.org/https://dx.doi.org/10.1186/s13018-018-0975-y

Ottenbacher, K. J., Hsu, Y., Granger, C. V., & Fiedler, R. C. (1996). The reliability of the functional independence measure: a quantitative review. *Archives of physical medicine and rehabilitation, 77*(12), 1226-1232.

Page, T. A., Gordon, S., Balchin, R., & Tomlinson, M. (2021). Caregivers' perspectives of the challenges faced with survivors of traumatic brain injury: A scoping review. *NeuroRehabilitation, 49*(3), 349-362. https://doi.org/10.3233/nre-210099

Patel, H. C., Bouamra, O., Woodford, M., Yates, D. W., & Lecky, F. E. (2010). Clinical article: mortality associated with severe head injury in the elderly. *Acta neurochirurgica, 152*(8), 1353-1357. https://doi.org/https://dx.doi.org/10.1007/s00701-010-0666-x

Pedersen, A. R., Severinsen, K., & Nielsen, J. F. (2015). The effect of age on rehabilitation outcome after traumatic brain injury assessed by the functional independence measure (FIM). *Neurorehabilitation and Neural Repair, 29*(4), 299-307. https://doi.org/http://dx.doi.org/10.1177/1545968314545171

Pennings, J. L., Bachulis, B. L., Simons, C. T., & Slazinski, T. (1993). Survival after severe brain injury in the aged. *Archives of surgery (Chicago, Ill. : 1960), 128*(7), 787-784.

Peters, M. E., & Gardner, R. C. (2018, Oct). Traumatic brain injury in older adults: do we need a different approach? *Concussion, 3*(3), Cnc56. https://doi.org/10.2217/cnc-2018-0001

Peterson, A. B., Xu, L., Daugherty, J., & Breiding, M. J. (2019). Surveillance report of traumatic brain injury-related emergency department visits, hospitalizations, and deaths, United States, 2014.

Phelan, E. A., & Ritchey, K. (2018, Dec 4). Fall Prevention in Community-Dwelling Older Adults. *Ann Intern Med, 169*(11), Itc81-itc96. https://doi.org/10.7326/aitc201812040

Pompucci, A., De Bonis, P., Pettorini, B., Petrella, G., Di Chirico, A., & Anile, C. (2007, Jul). Decompressive craniectomy for traumatic brain injury: patient age and outcome. *J Neurotrauma, 24*(7), 1182-1188. https://doi.org/10.1089/neu.2006.0244

Prasad, G. L., Anmol, N., & Menon, G. R. (2018, Mar). Outcome of Traumatic Brain Injury in the Elderly Population: A Tertiary Center Experience in a Developing Country. *World Neurosurg, 111*, e228-e234. https://doi.org/10.1016/j.wneu.2017.12.034

Public Health Agency of Canada. (2020). *Injury in review, 2020 edition: spotlight on traumatic brain injuries across the life course*.

Rabinowitz, A. R., Kumar, R. G., Sima, A., Venkatesan, U. M., Juengst, S. B., O'Neil-Pirozzi, T. M., Watanabe, T. K., Goldin, Y., Hammond, F. M., & Dreer, L. E. (2021). Aging with Traumatic Brain Injury: Deleterious Effects of Injury Chronicity Are Most Pronounced in Later Life. *Journal of neurotrauma, 38*(19), 2706-2713. https://doi.org/https://dx.doi.org/10.1089/neu.2021.0038

Raj, R., Mikkonen, E. D., Kivisaari, R., Skrifvars, M. B., Korja, M., & Siironen, J. (2016). Mortality in Elderly Patients Operated for an Acute Subdural Hematoma: A Surgical Case Series. *World neurosurgery, 88*(101528275), 592-597. https://doi.org/https://dx.doi.org/10.1016/j.wneu.2015.10.095

Ramage-Morin, P. L. (2008, Sep). Motor vehicle accident deaths, 1979 to 2004. *Health Rep, 19*(3), 45-51.

Ramanathan, D. M., McWilliams, N., Schatz, P., & Hillary, F. G. (2012). Epidemiological shifts in elderly traumatic brain injury: 18-year trends in Pennsylvania. *Journal of neurotrauma, 29*(7), 1371-1378. https://doi.org/https://dx.doi.org/10.1089/neu.2011.2197

Ritchie, L., Wright-St Clair, V. A., Keogh, J., & Gray, M. (2014, Jan). Community integration after traumatic brain injury: a systematic review of the clinical implications of measurement and service provision for older adults. *Arch Phys Med Rehabil, 95*(1), 163-174. https://doi.org/10.1016/j.apmr.2013.08.237

Roozenbeek, B., Maas, A. I., & Menon, D. K. (2013, Apr). Changing patterns in the epidemiology of traumatic brain injury. *Nat Rev Neurol, 9*(4), 231-236. https://doi.org/10.1038/nrneurol.2013.22

Ross, A. M., Pitts, L. H., & Kobayashi, S. (1992). Prognosticators of outcome after major head injury in the elderly. *The Journal of neuroscience nursing : journal of the American Association of Neuroscience Nurses, 24*(2), 88-93.

Ruge, T., Carlsson, A. C., Hellstrom, M., Wihlborg, P., & Unden, J. (2020). Is medical urgency of elderly patients with traumatic brain injury underestimated by emergency department triage? *Upsala journal of medical sciences, 125*(1), 58-63. https://doi.org/https://dx.doi.org/10.1080/03009734.2019.1706674

Sackett DL, S. S., Richardson WS, Rosenberg W, Hayes RB. (2000). *Evidence-based medicine: how to practice and teach EBM* (2nd ed. ed.).

Sahuquillo, J., & Dennis, J. A. (2019, Dec 31). Decompressive craniectomy for the treatment of high intracranial pressure in closed traumatic brain injury. *Cochrane Database Syst Rev, 12*(12), Cd003983. https://doi.org/10.1002/14651858.CD003983.pub3

Salive, M. E. (2013). Multimorbidity in older adults. *Epidemiol Rev, 35*, 75-83. https://doi.org/10.1093/epirev/mxs009

Salottolo, K., Carrick, M., Stewart Levy, A., Morgan, B. C., Slone, D. S., & Bar-Or, D. (2017). The epidemiology, prognosis, and trends of severe traumatic brain injury with presenting Glasgow Coma Scale of 3. *Journal of critical care, 38*(buy, 8610642), 197-201. https://doi.org/https://dx.doi.org/10.1016/j.jcrc.2016.11.034

Saverino, C., Swaine, B., Jaglal, S., Lewko, J., Vernich, L., Voth, J., Calzavara, A., & Colantonio, A. (2016). Rehospitalization After Traumatic Brain Injury: A Population-Based Study. *Archives of Physical Medicine & Rehabilitation, 97*, S19-S25. https://doi.org/10.1016/j.apmr.2015.04.016

Schneider, E. B., Hirani, S. A., Hambridge, H. L., Haut, E. R., Carlini, A. R., Castillo, R. C., Efron, D. T., & Haider, A. H. (2012, Oct). Beating the weekend trend: increased mortality in older adult traumatic brain injury (TBI) patients admitted on weekends. *J Surg Res, 177*(2), 295-300. https://doi.org/10.1016/j.jss.2012.06.022

Schonenberger, A., Billeter, A. T., Seifert, B., Neuhaus, V., Trentz, O., & Turina, M. (2012). Opportunities for improved trauma care of the elderly - a single center analysis of 2090 severely injured patients. *Archives of gerontology and geriatrics, 55*(3), 660-666. https://doi.org/https://dx.doi.org/10.1016/j.archger.2012.02.013

Schumacher, R., Müri, R. M., & Walder, B. (2017, Oct 7). Integrated Health Care Management of Moderate to Severe TBI in Older Patients-A Narrative Review. *Curr Neurol Neurosci Rep, 17*(12), 92. https://doi.org/10.1007/s11910-017-0801-7

Selassie, A. W., McCarthy, M. L., Ferguson, P. L., Tian, J., & Langlois, J. A. (2005). Risk of posthospitalization mortality among persons with traumatic brain injury, South Carolina 1999-2001. *The Journal of head trauma rehabilitation, 20*(3), 257-269.

Servadei, F., Compagnone, C., & Sahuquillo, J. (2007). The role of surgery in traumatic brain injury. *Current opinion in critical care, 13*(2), 163-168.

Sheriff, F. G., & Hinson, H. E. (2015, Feb). Pathophysiology and clinical management of moderate and severe traumatic brain injury in the ICU. *Semin Neurol, 35*(1), 42-49. https://doi.org/10.1055/s-0035-1544238

Shukla, D., Devi, B. I., & Agrawal, A. (2011, Jul). Outcome measures for traumatic brain injury. *Clin Neurol Neurosurg, 113*(6), 435-441. https://doi.org/10.1016/j.clineuro.2011.02.013

Skaansar, O., Tverdal, C., Ronning, P. A., Skogen, K., Brommeland, T., Roise, O., Aarhus, M., Andelic, N., & Helseth, E. (2020). Traumatic brain injury-the effects of patient age on treatment intensity and mortality. *BMC Neurology, 20*(1), 376. https://doi.org/http://dx.doi.org/10.1186/s12883-020-01943-6

Solomon, D., Kaminski, O., Schrier, I., Kashtan, H., & Stein, M. (2019, Dec). Isolated Traumatic Brain Injury in the Very Old. *Isr Med Assoc J, 21*(12), 779-784.

Spaniolas, K., Cheng, J. D., Gestring, M. L., Sangosanya, A., Stassen, N. A., & Bankey, P. E. (2010, Oct). Ground level falls are associated with significant mortality in elderly patients. *J Trauma, 69*(4), 821-825. https://doi.org/10.1097/TA.0b013e3181efc6c6

Stein, D. M., Kozar, R. A., Livingston, D. H., Luchette, F., Adams, S. D., Agrawal, V., Arbabi, S., Ballou, J., Barraco, R. D., Bernard, A. C., Biffl, W. L., Bosarge, P. L., Brasel, K. J., Cooper, Z., Efron, P. A., Fakhry, S. M., Hartline, C. A., Hwang, F., Joseph, B. A., Kurek, S. J., Moore, F. A., Mosenthal, A. C., Pathak, A. S., Truitt, M. S., & Yelon, J. A. (2018, Oct). Geriatric traumatic brain injury-What we know and what we don't. *J Trauma Acute Care Surg, 85*(4), 788-798. https://doi.org/10.1097/ta.0000000000001910

Suehiro, E., Koizumi, H., Kunitsugu, I., Fujisawa, H., & Suzuki, M. (2014). Survey of brain temperature management in patients with traumatic brain injury in the Japan neurotrauma data bank. *Journal of neurotrauma, 31*(4), 315-320. https://doi.org/https://dx.doi.org/10.1089/neu.2013.3057

Susman, M., DiRusso, S. M., Sullivan, T., Risucci, D., Nealon, P., Cuff, S., Haider, A., & Benzil, D. (2002). Traumatic brain injury in the elderly: increased mortality and worse functional outcome at discharge despite lower injury severity. *The Journal of trauma, 53*(2), 219-214.

Taussky, P., Hidalgo, E. T., Landolt, H., & Fandino, J. (2012). Age and salvageability: analysis of outcome of patients older than 65 years undergoing craniotomy for acute traumatic subdural hematoma. *World neurosurgery, 78*(3-4), 306-311. https://doi.org/https://dx.doi.org/10.1016/j.wneu.2011.10.030

Taylor, C. A., Bell, J. M., & Breiding, M. J. (2017). *Traumatic Brain Injury–Related Emergency Department Visits, Hospitalizations, and Deaths — United States, 2007 and 2013*.

Testa, J. A., Malec, J. F., Moessner, A. M., & Brown, A. W. (2005). Outcome after traumatic brain injury: effects of aging on recovery. *Archives of physical medicine and rehabilitation, 86*(9), 1815-1823.

Thapa, D. K., Visentin, D. C., Kornhaber, R., & Cleary, M. (2020, Dec). Prevalence and factors associated with depression, anxiety, and stress symptoms among older adults: A cross-sectional population-based study. *Nurs Health Sci, 22*(4), 1139-1152. https://doi.org/10.1111/nhs.12783

Thompson, H. J., Dikmen, S., & Temkin, N. (2012, Jan). Prevalence of comorbidity and its association with traumatic brain injury and outcomes in older adults. *Res Gerontol Nurs, 5*(1), 17-24. https://doi.org/10.3928/19404921-20111206-02

Thompson, H. J., McCormick, W. C., & Kagan, S. H. (2006, Oct). Traumatic brain injury in older adults: epidemiology, outcomes, and future implications. *J Am Geriatr Soc, 54*(10), 1590-1595. https://doi.org/10.1111/j.1532-5415.2006.00894.x

Tieves, K. S., Yang, H., & Layde, P. M. (2005, Feb). The epidemiology of traumatic brain injury in Wisconsin, 2001. *Wmj, 104*(2), 22-25, 54.

Tokutomi, T., Miyagi, T., Ogawa, T., Ono, J., Kawamata, T., Sakamoto, T., Shigemori, M., & Nakamura, N. (2008, Dec). Age-associated increases in poor outcomes after traumatic brain injury: a report from the Japan Neurotrauma Data Bank. *J Neurotrauma, 25*(12), 1407-1414. https://doi.org/10.1089/neu.2008.0577

Ushewokunze, S., Nannapaneni, R., Gregson, B. A., Stobbart, L., Chambers, I. R., & Mendelow, A. D. (2004). Elderly patients with severe head injury in coma from the outset--has anything changed? *British journal of neurosurgery, 18*(6), 604-607.

Utomo, W. K., Gabbe, B. J., Simpson, P. M., & Cameron, P. A. (2009, Sep). Predictors of in-hospital mortality and 6-month functional outcomes in older adults after moderate to severe traumatic brain injury. *Injury, 40*(9), 973-977. https://doi.org/10.1016/j.injury.2009.05.034

van Baalen, B., Odding, E., Maas, A. I., Ribbers, G. M., Bergen, M. P., & Stam, H. J. (2003, Jan 7). Traumatic brain injury: classification of initial severity and determination of functional outcome. *Disabil Rehabil, 25*(1), 9-18. https://doi.org/10.1080/dre.25.1.9.18

van Wessem, K. J. P., & Leenen, L. P. H. (2022). Geriatric polytrauma patients should not be excluded from aggressive injury treatment based on age alone. *European Journal of Trauma & Emergency Surgery, 48*(1), 357-365. https://doi.org/10.1007/s00068-020-01567-y

Vollmer, D. G., Torner, J. C., Jane, J. A., Sadovnic, B., Charlebois, D., Eisenberg, H. M., Foulkes, M. A., Marmarou, A., & Marshall, L. F. (1991). Age and outcome following traumatic coma : why do older patients fare worse ? *Journal of neurosurgery, 75*(Supplement), S37-S49. https://doi.org/10.3171/sup.1991.75.1s.0s37

Walder, B., Haller, G., Rebetez, M. M. L., Delhumeau, C., Bottequin, E., Schoettker, P., Ravussin, P., Brodmann Maeder, M., Stover, J. F., Zurcher, M., Haller, A., Wackelin, A., Haberthur, C., Fandino, J., Haller, C. S., & Osterwalder, J. (2013). Severe traumatic brain injury in a high-income country: an epidemiological study. *Journal of neurotrauma, 30*(23), 1934-1942. https://doi.org/https://dx.doi.org/10.1089/neu.2013.2955

Waltzman, D., Haarbauer-Krupa, J., & Womack, L. S. (2022, May 1). Traumatic Brain Injury in Older Adults-A Public Health Perspective. *JAMA Neurol, 79*(5), 437-438. https://doi.org/10.1001/jamaneurol.2022.0114

Wan, X., Liu, S., Wang, S., Zhang, S., Yang, H., Ou, Y., Zhao, M., James, L., Shu, K., Chen, J., & Lei, T. (2016). Elderly Patients with Severe Traumatic Brain Injury Could Benefit from Surgical Treatment. *World neurosurgery, 89*(101528275), 147-152. https://doi.org/https://dx.doi.org/10.1016/j.wneu.2016.01.084

Wang, J. W., Li, J. P., Song, Y. L., Tan, K., Wang, Y., Li, T., Guo, P., Li, X., Wang, Y., & Zhao, Q. H. (2016, May). Decompressive craniectomy in neurocritical care. *J Clin Neurosci, 27*, 1-7. https://doi.org/10.1016/j.jocn.2015.06.037

Wee, J. Z., Yang, Y. R. J., Lee, Q. Y. R., Cao, K., & Chong, C. T. (2016). Demographic profile and extent of healthcare resource utilisation of patients with severe traumatic brain injury: still a major public health problem. *Singapore medical journal, 57*(9), 491-496. https://doi.org/https://dx.doi.org/10.11622/smedj.2015162

Weir, J., Steyerberg, E. W., Butcher, I., Lu, J., Lingsma, H. F., McHugh, G. S., Roozenbeek, B., Maas, A. I., & Murray, G. D. (2012, Jan 1). Does the extended Glasgow Outcome Scale add value to the conventional Glasgow Outcome Scale? *J Neurotrauma, 29*(1), 53-58. https://doi.org/10.1089/neu.2011.2137

Wilson, J. T., Pettigrew, L. E., & Teasdale, G. M. (1998, Aug). Structured interviews for the Glasgow Outcome Scale and the extended Glasgow Outcome Scale: guidelines for their use. *J Neurotrauma, 15*(8), 573-585. https://doi.org/10.1089/neu.1998.15.573

Wutzler, S., Lefering, R., Wafaisade, A., Maegele, M., Lustenberger, T., Walcher, F., Marzi, I., Laurer, H., & TraumaRegister, D. G. U. (2015). Aggressive operative treatment of isolated blunt traumatic brain injury in the elderly is associated with favourable outcome. *Injury, 46*(9), 1706-1711. https://doi.org/https://dx.doi.org/10.1016/j.injury.2015.02.013

Yap, S. G. M., & Chua, K. S. G. (2008). Rehabilitation outcomes in elderly patients with traumatic brain injury in Singapore. *The Journal of head trauma rehabilitation, 23*(3), 158-163. https://doi.org/https://dx.doi.org/10.1097/01.HTR.0000319932.15085.fe

Yokobori, S., Yamaguchi, M., Igarashi, Y., Hironaka, K., Onda, H., Kuwamoto, K., Araki, T., Fuse, A., & Yokota, H. (2016). Outcome and Refractory Factor of Intensive Treatment for Geriatric Traumatic Brain Injury: Analysis of 1165 Cases Registered in the Japan Neurotrauma Data Bank. *World neurosurgery, 86*(101528275), 127-133.e121. https://doi.org/https://dx.doi.org/10.1016/j.wneu.2015.09.105

You, W., Feng, J., Tang, Q., Cao, J., Wang, L., Lei, J., Mao, Q., Gao, G., & Jiang, J. (2016). Intraventricular intracranial pressure monitoring improves the outcome of older adults with severe traumatic brain injury: an observational, prospective study. *BMC anesthesiology, 16*(1), 35. https://doi.org/https://dx.doi.org/10.1186/s12871-016-0199-9

Young, J. S., Hobbs, J. G., & Bailes, J. E. (2016, Sep). The Impact of Traumatic Brain Injury on the Aging Brain. *Curr Psychiatry Rep, 18*(9), 81. https://doi.org/10.1007/s11920-016-0719-9

Zarshenas, S., Colantonio, A., Alavinia, S. M., Jaglal, S., Tam, L., & Cullen, N. (2019). Predictors of discharge destination from acute care in patients with traumatic brain injury: a systematic review. *The Journal of head trauma rehabilitation, 34*(1), 52-64.

Zurlo, A., & Zuliani, G. (2018, Mar). Management of care transition and hospital discharge. *Aging Clin Exp Res, 30*(3), 263-270. https://doi.org/10.1007/s40520-017-0885-6

Zygun, D. A., Laupland, K. B., Hader, W. J., Kortbeek, J. B., Findlay, C., Doig, C. J., & Hameed, S. M. (2005, Feb). Severe traumatic brain injury in a large Canadian health region. *Can J Neurol Sci, 32*(1), 87-92. https://doi.org/10.1017/s0317167100016930