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NEUROTRAUMA (M KUMAR, SECTION EDITOR)

# Integrated Health Care Management of Moderate to Severe TBI in Older Patients—A Narrative Review

**Rahel Schumacher**[1] · **René M. Müri**[1,2] · **Bernhard Walder**[3]

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**Abstract**
*Purpose of Review* Traumatic brain injuries are common, especially within the elderly population, which is typically defined as age 65 and older. This narrative review aims at summarizing and critically evaluating important aspects of their health care management in covering the entire pathway from prehospital care to rehabilitation and beyond.
*Recent Findings* The number of older patients with traumatic brain injury (TBI) is increasing, and there seem to be differences in all aspects of care along their pathway when compared to younger patients. Despite a higher mortality and a generally less favorable outcome, the current literature shows that older TBI patients have the potential to make significant improvements over time.
*Summary* More research is needed to evaluate the most efficient and integrated clinical pathway from prehospital interventions to rehabilitation as well as the optimal treatment of older TBI patients. Most importantly, they should not be denied access to specific treatments and therapies only based on age.

**Keywords** Elderly · Traumatic brain injury · Epidemiology · Prehospital care · Hospital care · Rehabilitation

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✉ Rahel Schumacher
rahel.schumacher@dbmr.unibe.ch

[1] Department of Neurology, University Neurorehabilitation, Inselspital, University Hospital Bern, Freiburgstrasse 10, 3010 Bern, Switzerland

[2] Gerontechnology and Rehabilitation Group, University of Bern, Bern, Switzerland

[3] Division of Anaesthesiology, University Hospitals of Geneva, Geneva, Switzerland

## Introduction

Traumatic brain injury (TBI) is a significant public health concern with a high number of emergency room visits and hospitalizations [1, 2••]. It is a major cause of death due to injury in high-income countries [3] and can lead to chronic disability. TBI management from prehospital care to post-rehabilitation care has considerable costs [4]. In the last years, an increase in the number of elderly patients, typically defined as age 65 and above, suffering a TBI has been observed in high-income countries [5, 6]. Awareness regarding possible special needs of this patient group is increasing, which is also reflected in the growing number of articles published on the topic during the last 5 years. This narrative review focuses on the integrated health care of moderate to severe TBI in older patients. We aim at summarizing and critically evaluating the latest findings on epidemiology; diagnostic, prognostic, and therapeutic interventions during the entire clinical pathway in prehospital, in-hospital acute, and rehabilitation care; and the long-term outcomes of this patient group. Therefore, no comprehensive summary of the modern management of all TBI patients will be given. For a recent review on the intensive care management of severe TBI see Stocchetti et al. [7], and for a review on mild TBI see Levin & Diaz Arrastia [8].

## Epidemiological Characteristics

The incidence of moderate and severe TBI in older patients in highly-developed countries increased in the last years, as current data from Australia [9], North America [6, 10–14], and Europe [15–21] indicate. In Sweden, for instance, an overall decrease of the TBI incidence from 230/100,000 inhabitants/year to 156/100,000 inhabitants/year was observed over 23 years, based on registry data. However, an increased

incidence was observed in patients > 65 years, which was even more pronounced in patients > 85 years [17•]. The latter showed an increase of TBI incidence from around 450/100,000 to 800/100,000 inhabitants per year for men and to 600/100,000 inhabitants per year for women. The Swedish study may, however, underestimate the real incidence of TBI because it is based on health registration data which has been shown to underrate real incidence [22]. In a recent prospective Swiss investigation of adult *severe* TBI patients, the incidence of older TBI patients (> 65 years) was three times higher than the incidence of younger TBI patients (22.4/100,000 inhabitants/year versus 7.9/100,000 inhabitants/year) [2••]. In high-income countries, about one third of all patients with severe TBI admitted to trauma centers are > 65 years [2••]. Around 75% of adult TBI patients are typically male, but in the elderly population, a considerably higher percentage of female patients were observed [2••, 6, 12, 23–25].

The increased incidence is related to a higher number of unintentional falls, about two thirds occurring at home [9, 26]. Falls are the main trauma mechanism in older patients; 75% or more of older TBI patients had a fall, usually from low heights [2••, 24, 27]. Pre-existing neurological conditions such as dementia, hemiplegia, Parkinson's disease, or multiple sclerosis may contribute to falls [28, 29]. In addition, falls may also be associated with cardiovascular (antihypertensives) and psychiatric medication (benzodiazepines) [30]. The highest incidence of falls was observed in patients already living in a nursing home [23].

The risk of death and dependency increases with age [31], and TBI patients > 80 years show a particularly high mortality rate [32]. Early mortality at 14 days was 41% in older patients with severe TBI, whereas it was 25% in younger patients [2••]. Furthermore, older, frail patients with TBI living in a nursing home had higher mortality rates (23%) than older patients with TBI living at home (15%) [33]. Apart from pre-existing chronic diseases, older patients with TBI frequently have additional acute medical problems, such as pneumonia and decompensated cardiac failure. Focusing on a single death cause, for instance in registry data, may not appropriately reflect the contribution of other diseases and thereby lead to inaccurate estimates of mortality due to TBI in older patients [34].

## Prehospital Assessments and Adapted Interventions

The three main aims of the prehospital period include the assessment of TBI, triage, and avoidance of secondary brain lesions. In older patients, the diagnosis of TBI on scene is not always evident if the fall was not observed; stroke, intoxication, sepsis including pneumonia, or cardiac failure may be other hypotheses for changes in consciousness and cognitive capacities. The aim of the initial triage should be to identify patients needing a neurosurgical intervention in a specialized trauma center (optimal hospital destination). There is evidence of under-triage especially in older adults (> 55 years), who are less likely to be initially transported to a trauma center following a TBI [35, 36].

The classical assessment tool during the prehospital period, which is often used as a triage tool for further management, was and is the Glasgow Coma Scale (GCS). However, it has recently been shown that GCS scores were often unreliable in older TBI patients; i.e., the assessment underestimated TBI severity [37, 38, 39•, 40]. This underestimation seemed to be more pronounced in women than in men [25].

To date, no specific prehospital prediction models or tools for prehospital triage of older TBI patients are available. Several lines of research currently aim at advancing the highly relevant topic of prediction and triage decision for TBI patients on scene. One approach is the inclusion of supplementary vital parameters, for instance using the "head injury straight to neurosurgery" triage rule [41], or the inclusion of a supplementary overall estimation of vital severity by prehospital health care provider [42]. Another approach is the use of diagnostic devices on scene, in particular near infrared spectroscopy (NIRS) [43] or mobile cerebral tomography (CT) scanning [44].

Avoidance of secondary brain lesions related to reduced cerebral perfusion and cerebral hypoxia is a further aim of prehospital care. Arterial hypotension during the prehospital period was identified as independent risk factor of early mortality after TBI [45]. Many older patients have chronic treated or untreated arterial hypertension. Therefore, the proposed systolic pressure of at least 90 mmHg after TBI may be too low. A recent study based on a prehospital database including patients between 10 and 99 years gave indirect evidence for this hypothesis in concluding that the blood pressure cutoff of systolic 90 mmHg is, in general, too low [46•]. Furthermore, an optimal blood pressure (for instance, systolic blood pressure at 120 mmHg) could decrease mortality [47]. However, artificially increased prehospital blood pressure in older TBI patients, for instance with catecholamines, should be tested in a randomized controlled trial with relevant outcome measures.

## In-Hospital Acute Care Management

In older patients with moderate or severe TBI, subdural (30 to 62%) and subarachnoid hemorrhage (17 to 20%), or a combination of both, may be observed on imaging [17•, 33, 48]. Cerebral contusions are also common. Older patients may benefit from aggressive neurosurgical and intensive care treatment with about one third to one half of the patients showing a favorable outcome depending on age and TBI severity [27, 49]. However, based on epidemiologic data, frail patients—often living in nursing homes—may not benefit from an invasive TBI management. In addition, it is suspected that highly invasive neurosurgical treatment may be associated with worse outcomes in older patients with TBI [50].

Standardized documentation of all neurosurgical interventions in younger and older TBI patients could be a first step towards an improved estimate of optimal neurosurgical strategy [51]. It is hypothesized that minimally invasive methods for hematoma evacuation could improve outcome; however, formal randomized trials are needed to test this hypothesis.

Older patients are often treated with antithrombotic and anticoagulant drugs; therefore, there is a risk of increased intracranial bleeding with progressive hemorrhagic injury [52]. In a recent epidemiological study, 29% of all older patients with severe TBI had anticoagulants [2••]. In older patients with TBI, the risk and benefits of anticoagulation after moderate and severe TBI has, however, to be critically appraised. *Low*-dose of anticoagulants in TBI patients > 65 years were not associated with worse Glasgow Outcome Scale Extended (GOSE) at hospital discharge [53], and the net benefit seemed to outweigh the long-term risks of hemorrhage in a group also including mild TBI [54]. Also, antithrombotic agents, in particular *low*-dose aspirin, in patients > 65 years undergoing emergency neurosurgery for traumatic intracranial hemorrhage, were not associated with mortality or hospital lengths of stay [55]. However, antithrombotic drugs in therapeutic range but not antiplatelet medication aggravated fatality [48], and a study on new direct oral anticoagulants indicates that mortality in older TBI patients might be lower compared to warfarin [56].

Other aspects in geriatric patients, such as cerebral atrophy with increased intracranial space, may play a role in intracranial hemorrhage and, potentially, in avoiding fatal intracranial hypertension after TBI before surgical evacuation [57]. It can therefore be speculated that an unmeasured bias might explain why there seems to be no association between outcome after TBI and *low*-dose antithrombotic and anticoagulant medication. In any case, specific antidotes to reverse bleeding associated with antithrombotic drugs and anticoagulants should be considered. Normalization of coagulopathy early after hospital admission may improve outcome also in older TBI patients [58].

Early identification of the patients who will probably not show a favorable outcome is highly relevant to avoid proxies' overestimation of benefit as well as underestimation of harm. Validated, predictive models would be relevant for adequate decision-making in the first hours after hospital admission and after the first assessment, in particular in identifying patients who are less likely to benefit from aggressive treatment. Ideally, optimal prediction models at hospital admission should be the base for complex decision-making of the optimal and adapted clinical pathways after TBI, including avoidance of medical futility and improved palliative care for end-of-life situations.

However, most available models in TBI that include a large number of older patients have methodological limitations, such as calibration (agreement between the predicted risk and the observed risk of the outcome) and external validation [31, 59]. Validated prediction models for younger TBI patients (CRASH model) may not be sufficiently discriminative in older patients [24]. Furthermore, predictions critically depend on whether only isolated TBI or patients with additional injuries are considered [25] and how existing comorbidities are taken into account. While it is important to estimate the influence of each risk factor individually, one has to bear in mind that about 75% of an elderly TBI cohort did not have an isolated TBI [25] and many have comorbidities [10, 24]. A combination of different risk factors such as age (including frailty (60) and nursing home residency), GCS, abbreviated injury score of head (AIS head), and cranial CT scoring might predict with high discrimination and high calibration certain outcomes such as mortality, posttraumatic complications, and disability [61, 62]. Further research is needed to elucidate whether specific biomarkers might improve prediction after TBI in general and, particularly, in older TBI patients [63–65].

A second holistic assessment for strategic decision-making may be performed 72 h after aggressive TBI treatment. In particular, in non-responders to care, a decision-making process including end-of-life care should be considered, also with respect to the very high mortality of 71.8% at 1 year [66]. The knowledge of a patient's personal health care priorities before TBI should be a key element for decision-making. The availability of an antecedent end-of-life-decision can be helpful and may avoid marginalization of a patient's will [67].

Older TBI patients with reasonable chance of favorable outcome may have a benefit of early mobilization and early rehabilitation during acute care in order to avoid cutaneous pressure injury, thrombosis, atelectasis, and pneumonia. These early rehabilitative measures, however, stand in contrast to the prolonged bed rest, a measure taken to avoid secondary brain damage, such as delayed vasospasm and oedema [68]. To date, such an enhanced recovery approach has not been tested in older TBI patients.

## Rehabilitation for Whom, Why, and How?

The changing epidemiology of TBI is to some extent reflected in the referrals to inpatient rehabilitation. Current data from the USA show that the mean age and proportion of female patients receiving inpatient rehabilitation increases [69, 70••]. Unfortunately, many studies do not state what inpatient rehabilitation comprises, for instance whether patients are sent to specialized neurorehabilitation, and differences between health care systems complicate comparisons of referrals to inpatient rehabilitation.

Recent studies analyzed access to specialized neurorehabilitation in terms of patient characteristics, delays in admission, and continuity of care. It was found that younger age and male gender were predictors of being referred to neurorehabilitation, thus pointing at possible inequities in access for older and female patients [71•, 72]. Additionally, older patients

were more likely to be admitted indirectly (i.e., stayed in another hospital or non-specialized rehabilitation before), which led to delays and was associated with lower functional independence [73•]. The influence of age on referrals to rehabilitation was also highlighted in a recently published survey among 70 European trauma centers. Nearly half of the respondents (usually rehabilitation physicians or neurosurgeons) indicated that age is an important factor in their decision to refer a patient to specialized neurorehabilitation [74].

One possible reason for not referring older TBI patients to specialized inpatient neurorehabilitation is the assumption that they will not make substantial progress. This assumption is on one hand based on published evidence with older adults having worse outcomes than younger adults. On the other hand, it might be speculated that convictions about older persons' naturally declining cognitive capacities, possibly aggravated by the high prevalence of neurodegenerative diseases in this age group, additionally bias the decision process. Furthermore, as highlighted by previous studies [71•, 75], referral decisions are based on a variety of interrelated factors and include not only patient and injury characteristics, but also structural realities, for instance, a reduced availability of beds in inpatient neurorehabilitation, which might increase the need to justify a patient's referral to inpatient rehabilitation.

As adults older than 65 are typically retired, return to work is not the main goal of rehabilitation anymore, in contrast to the younger TBI population. More than in younger TBI patients, rehabilitation in older patients focuses on social integration, a high quality-of-life, and the avoidance of institutionalization [76, 77]. These differences in rehabilitation goals might affect the decision for or against specialized neurorehabilitation referral as well as the type and amount of therapies offered.

One recent study evaluated the type and amount of therapy patients receive during inpatient rehabilitation [70••]. The vast majority of older patients received physical therapy, occupational therapy, and speech-and-language therapy, however on average less therapy per week than younger patients. This difference was pronounced for psychological and recreation therapy, which only a part of the older patients received and again to a lesser extent than the younger patients. Additionally, older patients had a shorter length of stay, resulting in a lower total amount of therapy.

Another study explored the evolution of older TBI patients during inpatient rehabilitation [78]. Overall, even though older patients had lower Functional Independence Measurement (FIM) scores at admission to and at discharge from inpatient rehabilitation, the absolute change in FIM score was similar in older and younger TBI patients, as similarly reported by Pedersen et al. [79]. Comparable results for another measure of functional recovery, the Barthel Index, were also found in stroke patients [80]. Older patients thus demonstrate potential for a significant increase of functional status and should therefore not be excluded from inpatient rehabilitation.

Current guidelines recommend that the cognitive functions of all patients sustaining a moderate to severe TBI should be assessed by the respective specialist (neuropsychologist, occupational therapist, and speech-and-language pathologist) [81]. Thereafter, the patients' cognitive profile as well as premorbid activities and goals should be taken into consideration to decide if and what type of rehabilitation should be offered [81]. However, cognitive rehabilitation research typically includes patients under the age of 65 [81] and no specific guidelines for older patients have been issued so far. Furthermore, depending on the organizational structures, such a comprehensive assessment is often only done within a specialized neurorehabilitation setting, thus requiring that patients are referred there in the first place.

It is assumed that patients who are discharged home or to a long-term care facility from in-hospital acute care will not get targeted outpatient rehabilitation [75]. This is important given the finding that access to community rehabilitation services significantly predicted independence of patients above the age of 55 2 to 4 years after TBI [82]. Furthermore, if older TBI patients have access to outpatient or day-care facilities convenient to their age group, the majority of them might be predominantly targeted at patients with neurodegenerative diseases.

The reality of most health care systems all over the world demands that interventions are cost-effective. One study with severe TBI patients up to the age of 55 found that a continuous chain of rehabilitation led to lower costs and better health over the course of 5 years compared to a broken chain (i.e., a delayed admission to specialized rehabilitation) [83•]. To what extent this finding might be applicable to older patients remains to be elucidated. Additionally, it has been shown that the costs incurred by subgroups of elderly patients during 1 year following a TBI of any severity were comparable but varied in their cost drivers [84]. The oldest (75–84 years) had a lower number of physician and health professional visits but a higher number of rehospitalization. It might be possible to target these apparent differences in the management of elderly TBI patients and thereby not only improve the outcome but also the cost-effectiveness of their care.

## Outcomes of Older TBI Survivors

Typically, discharge destination, various functional measures, or measures to assess quality of life are used as outcome measures at different time points after a TBI. Institutionalization is often considered as an unfavorable outcome, and one goal of the care after TBI is to avoid discharge to a long-term care. About 1 of 12 survivors of a fall-related TBI needed permanent nursing home placement [33]. Age, together with living alone and lower levels of independence, was a significant predictor of discharge to an institutional setting after inpatient rehabilitation [5, 77], and more women were discharged to

care facilities after in-hospital acute care [85]. The authors speculate that the increased discharge to care facilities might be due to the fact that women often are the primary caregiver and no other persons could assume this role. Furthermore, women are more likely to live alone, which complicates returning home. However, it may be questioned if all types of institutionalization have to be regarded as unfavorable outcome in this age group. In terms of offering a stimulating environment to preserve or improve cognitive functions, some institutions might offer more to an individual who might otherwise live relatively isolated at home. Therefore, other outcome measures than discharge destination may be more appropriate for older patients.

A variety of functional measures are used as another proxy for outcome after TBI, the most commonly used being the Glasgow Outcome Scale (GOS), the GOS Extended (GOSE), and the Functional Independence Measure (FIM). In a meta-analysis on GOS scores of patients older than 60 years, McIntyre et al. found high mortality rates within 1 year post TBI (42.5–79.9%) but favorable outcomes in 56 and 38% of the moderate and severe TBI survivors, respectively [49]. They argue that favorable outcomes might be underestimated as some of the included studies measured GOS relatively early post TBI, while it has been shown that 1 year post TBI seems to be more adequate. This is in line with newer findings showing that GOSE scores improved between 3 and 12 months after severe TBI in 80% of the patients older than 65 years [86]. Fifty-six percent of the patients aged 65–75 years and 14% of the patients aged 75 and above showed a favorable outcome (defined as GOSE 5 or above) at 12 months [24], and 30% of the survivors aged 65 and above showed an upper good recovery in another study [87•].

The study by Haller et al. further pointed out that GOSE may fail to detect patient-relevant improvements. Even though older patients in this study, in contrast to other studies, did not show a significant improvement of GOSE scores between 3 and 12 months after severe TBI their physical health-related quality of life improved. It has thus been suggested that measures assessing the health-related quality of life offer a more complete estimate of the outcome by capturing the subjective experience of patients [88]. Several studies even found that older age was associated with a higher quality of life or life satisfaction after TBI [86, 89, 90]. Nevertheless, an important number of older TBI patients experiences negative changes in well-being and quality of life, but the research in this field is quite limited [91].

Moderate to severe TBI is not only associated with an increased mortality rate shortly after the TBI (e.g., at 24 h or 14 days) but also in the long-term. However, it was shown that

**Table 1** Key messages and future research questions for older patients with moderate to severe traumatic brain injury (TBI)

| Topic | Main conclusions |
|---|---|
| Epidemiology | Incidence of moderate and severe TBI in older patients increases |
| | Incidence of moderate and severe TBI is higher compared to younger patients |
| | Rate of female gender is higher in older TBI patients |
| | Mechanism is most often falls (at home) |
| | Mortality is high and exceeds younger patients' mortality |
| Prehospital | Risk of under-triage |
| | Diagnostic accuracy of GCS is reduced |
| | No specific triage tool (prediction) available |
| | Low blood pressure may be a particular risk |
| In-hospital acute care | Aggressive treatment is indicated in 1/3 to 1/2 of older TBI patients |
| | Optimal invasivity of management is to define |
| | A particular concern are antithrombotic and anticoagulant drugs—a consensus of management is to define |
| | No externally validated prediction model available |
| | Enhanced recovery programmes should be tested |
| Neurorehabilitation | Risk of under-treatment, in particular for female patients |
| | Functional improvement during neurorehabilitation |
| | Optimal cognitive rehabilitation is to define and to test |
| | Overall health care costs including neurorehabilitation for elderly TBI patients have to be estimated |
| Outcome of survivors | Disability decreases slightly over time |
| | Quality of life increases over time |
| Implications | Very limited research including older TBI patients |
| | Prevention of falls should have a high priority in research |
| | Research in ethics and management of complex pathway should be established |

the mortality rate of patients who received inpatient rehabilitation was only greater than expected for the age in patients younger than 85 years [92]. In addition to the increased long-term mortality, a deterioration of global outcome as early as 5 years after a TBI has been observed [90]. This finding bears significance for the discussion about the relationship of TBI and normal aging or neurodegenerative diseases [93], which is, however, beyond the scope of this review.

In conclusion, older patients show smaller progress in some studies but many of the surviving patients improve and are relatively satisfied with their quality of life. As the methodologies of some studies tend to underestimate older patients' outcomes, for instance due to too early assessments, it might be worth to review the time points as well as the outcome measures in use. Furthermore, an interdisciplinary discussion about definitions of favorable versus unfavorable outcomes could have implications for predictions and management during their entire pathway. In fact, several authors advanced the hypothesis that the worse outcome in older patients might constitute a self-fulfilling prophecy [7, 74, 94•]. Taking the long-term outcome findings into account, it is important to consider TBI as a "lifelong health condition," warranting a chronic disease management model [90, 95–98].

## Future Implications

Despite some initiatives in TBI research in general, the specific TBI research in older patients is limited and more research in this population is clearly needed [19•, 91], as also summarized in Table 1. It is expected that the number of older patients with TBI due to falls will continue to increase over the next decades. With the main trauma mechanism being falls, prevention programmes [99] and research into their effectiveness are of high importance [6]. Further axes of prevention in an older population at risk for falls could be the restriction of the use of central-acting medication, including atypical antipsychotic medication [100], sedative drugs, and the therapeutic anticoagulation with warfarin [48]. Validated prehospital and hospital prediction models for older TBI patients are also of high priority, which should include an assessment of frailty [60••]. Ethical guidelines for optimal TBI management in in-hospital acute care should be established on best available evidence to avoid overtreatment and unnecessary suffering before hospital death [67]. The most efficient integrated clinical pathways from prehospital interventions to rehabilitation as well as the optimal treatment strategies have to be evaluated for this older and vulnerable population to facilitate best patient outcomes. In particular, more research should be performed regarding the management of complex pathways, in order to avoid lack of coordinated care post discharge [84]. Furthermore, future research may include studies on cognitive reserve [101, 102].

## Conclusions

Older patients should be given special consideration throughout their entire pathway after a traumatic brain injury. TBI management in these patients is very complex, and they differ in various aspects, such as trauma mechanism, comorbidities, physical and cognitive reserve, social situation, and therapeutic goals from a younger population. However, as in other patient cohorts, inter-individual variability is also high and should not be neglected. Most importantly, an integrated management is crucial and this patient group should not be denied access to specific treatments and therapies only based on their age.

### Compliance with Ethical Standards

**Conflict of Interest** The authors declare that they have no conflict of interest.

**Human and Animal Rights and Informed Consent** All reported studies/experiments with human or animal subjects performed by the authors have been previously published and complied with all applicable ethical standards (including the Helsinki declaration and its amendments, institutional/national research committee standards, and international/national/institutional guidelines).

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