Severe neurotrauma in Switzerland: have short-term outcomes improved?

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Summary

Neurotrauma has a high incidence in high-income countries (790 per 100,000 population per year) and can be considered a silent epidemic. Severe traumatic brain injury (TBI) is a major burden for societies and is associated with high costs for both immediate and long-term care. Population-based studies including patients with severe TBI are rare. A recent cohort study in Switzerland observed an incidence of 11 / 100,000 population / year. Mortality rate at 14 days post-injury was 30% in Switzerland and was associated with the severity of the injury and the age of the injured person. Thirty-five percent of patients were >65 years; in this subpopulation the incidence (22/100,000/year) and death rate (41%) were higher; this high proportion of elderly patients in this setting is new. A decrease in disability in the first year after TBI was observed in large multicentre cohort studies including the Swiss cohort study. There is some evidence that the speed of decrease of disability over time is associated with intensive neurorehabilitation. In conclusion, short-term outcome may have improved for younger patients over recent years, but this improvement may be masked by the higher proportion of elderly patients with less favourable outcomes. Additionally, we propose that clinical pathways from the prehospital period to rehabilitation could be improved, and in turn allow a higher level of positive outcomes not only in young but also in elderly patients.

Key words: traumatic brain injury; head injury; mortality; old; Glasgow Outcome Scale; disability; functional outcome; overview

Introduction

Neurotrauma, in particular severe traumatic brain injury (TBI) – which makes up about 5% of all neurotrauma – is a worldwide health concern and a great burden for a society. Costs of care are reported to be substantial (about $250,000 Australian [180,000 CHF] per patient with severe TBI) [1]. Neurotrauma has been considered a "silent epidemic", with an incidence of 790 per 100,000 individuals per year [2] in New Zealand, for example. "Silent" because our society seems to accept a high prevalence of neurotrauma as an inevitable fact, which may explain why brain research is underfunded [3]. Interestingly, newspapers and television regularly report on spectacular accidents involving young athletes that result in severe TBI, but fail to integrate those cases into existing scientific evidence yielded by epidemiological studies. The epidemiological evidence just mentioned indicates a considerable increase in severe TBI in elderly individuals that results from falls [4].

In Switzerland, research on neurotrauma is rare. Among the few studies that have investigated neurotrauma, single centre observations are the most common. In the last 10 years a national research network – entitled "Patient-relevant Endpoints after Brain Injury from Traumatic Accidents" (PEBITA) – has been conducting research in the domain of severe TBI. The goal of this research network is to increase knowledge about severe TBI in Switzerland, and make data transparent and available for the public by reporting and standardizing patient recovery from the prehospital setting to the post-rehabilitation period. The PEBITA network intends to increase the knowledge and perception of the neurotrauma epidemic. In view of the limited high quality evidence of effective interventions for patients with severe TBI, the research network decided to focus on an epidemiological approach, which can identify specific population-based risk factors for Switzerland and thus other high-income countries.

The present review aims at summarising incidence and short-term outcome in adult patients suffering from severe TBI in Switzerland and other high-income countries. Furthermore, it will identify potential factors that may improve the outcome after a severe TBI. Short-term outcomes include mortality and functional disability (0.5 to 12 months), long-term outcomes include neuropsychological deficits, quality-of-life and burden on the family (3 months to many years).

Incidence

Reported population-based estimates of the incidence may vary considerably because of differences in inclusion criteria across studies (table 1). First, the estimated incidence is higher if data collection starts in the prehospital period

as opposed to after hospital admission. Second, estimated incidence depends on the inclusion criteria for severe TBI: If at hospital admission a Glasgow Coma Score (GCS) <9 is used as inclusion criterion, the incidence will be lower compared with an inclusion based on the abbreviated injury score of the head (HAIS) >3. The estimated incidence will also be different if the International Classification of Diseases (ICD) code is used as inclusion criterion. The ICD is the diagnostic tool commonly used at the end of the acute hospital stay; consequently, it may be more useful for retrospective studies or studies starting *after* the acute hospital stay. Third, there is considerable inter-rater variability for the GCS at hospital admission, which may bias the estimates of incidence [5]. Thus, results of all population-based investigations, including the ones involving individuals with a TBI, have to be interpreted with caution. Most population-based studies suffer from underestimation of the "true" incidence. This underestimation is related to the absence of data for patients without contact with healthcare providers.

Population-based estimates have rarely been performed in high-income countries with a low rate of penetrating TBI [6–10], and among the few investigations incidences have varied substantially (table 1). This variation could be partly related to the different inclusion criteria. Two population-based studies used the same inclusion criterion: HAIS >3 [7, 9]. A recent investigation in Switzerland reported an incidence of 11 per 100,000 individuals per year [6]. A French study in the rural region of Aquitaine estimated the incidence of severe TBI to be 17 per 100,000 individuals per year in 1996 [7]. The distribution of HAIS was similar in both studies (HAIS 4: 41.1%, HAIS 5: 58.9%), including the ratio of multiple trauma (32.2%). The lower incidence in the Swiss population may be related to increased traffic safety and/or to different risk behaviours of the different populations.

A population-based study in Norway showed the incidence to be 4 to 5 per 100,000 individuals per year using the ICD-10 codes, and GCS <9 [6]. If only patients with a GCS <9 on scene were taken into account for the Swiss TBI population, the incidences in either study would be similar (5 per 100,000 individuals per year in Switzerland, 4 to 5 per 100,000 individuals per year in Norway). Thus, incidences in both countries should have been similar if identical inclusion criteria had been chosen.

Short-term mortality

Mortality is highest in the first few days after severe TBI. Main risk factors are the severity of the TBI and the patient's age (i.e., the greater the severity and the older the patient, the greater the mortality). The severity of additional injuries to other body parts associated with hypovolaemic shock and arterial hypotension may further contribute to mortality [11]. It is possible that improvement over time in care of patients with severe TBI may have led to the lower reported mortality rates in newer studies. However, in a recent metaregression, no such trend could be observed since 1990 [12].

Most large multicentre cohort studies of patients with severe TBI in high-income countries observed mortality rates between 30% and 45% (tables 2 and 3); [2, 6–10, 13–19]. Two studies that included only an urban population with an unknown injury severity score (ISS) reported higher death rates (47% and 49%) and one study in Australia with a lower TBI severity reported a death rate of 18%. Interestingly, the Swiss population-based study, which included the oldest population (median age of 55 years), did not report the highest mortality of all the studies. This may speak for the acceptability of the overall quality of care for patients with TBI in Switzerland.

Two population-based studies that used the same inclusion criteria (i.e., HAIS >3) [7, 9], reported similar death rates per HAIS category (HAIS 4: 7.7% in Aquitaine, 10.4% in Switzerland; HAIS 5: 46.0% in Aquitaine, 40.9% in Switzerland). Considering that age is one of the most important risk factors for poor post-TBI outcome [20], the similar mortality rates in the Swiss study in 2007–11 (with older patients) and the French study in 1996 (with comparably younger patients) may suggest that care and general safety measures have improved over recent years in Europe, thus potentially counterbalancing the effects of age on mortality. In other words, if mortality rates are similar in the two investigations with similar injuries but with two different age distributions, the one with the older population may have been carried out in a region with superior care.

The population-based study in Norway was carried out in a similar time-period to the Swiss study. Similarities between the studies included cause distribution, age distribution, death rate (29%) and an increased early mortality rate (within 48 hours following injury). These studies sup-

Table 1: Recent population-based studies of severe traumatic brain injury in adults and in high-income countries (last 20 years).

First author	Journal	Year of publication	Inclusion criteria	Region	Youngest included patient	Inception period	Incidence (per 100,000 individuals per year)
Walder	J Neurotrauma	2013	HAIS >3	Switzerland	16	2007–2010	10.6
Andelic - Norwegian Cohort	Neuroepidemiology	2012	ICD-10 and GCS <9	Norway	16	2009–2010	5.2/4.1
Zygun	Can J Neurol Sci	2005	ISS >11, GCS <9, ICP monitoring, herniation in CT	Calgary (Canada)	18	1999–2002	11.4
Masson	J Trauma	2001	HAIS >3	Aquitaine (France)	any	1996	17.3
Bouillon	Restor Neurol Neurosci	1999	GCS <9 or HAIS >2	Cologne (Germany)	any	1990–1996	9.3

CT = computed tomography; GCS = Glasgow Coma Score; HAIS = abbreviated Head Injury Score; ICD = International Classification of Diseases; ICP = intracranial pressure; ISS = Injury Severity Score

port previously reported evidence that mortality is linked to the severity of the injury and the age of the injured [21]. The time-point when mortality rates were measured and reported differed across studies. Calls for consensus on the definition of the time-point of the mortality assessment in neurotrauma research are justified. We propose that this time-point should be around 14 days postinjury, because at this time most patients with severe TBI are still inpatients.

Short-term disability outcome

Most often disability in patients with neurotrauma is measured with the Glasgow Outcome Scale (GOS) or, more recently, with the Glasgow Outcome Scale extended (GOSE). The scale includes the items death, vegetative state, severe disability, moderate disability and good recovery. The GOSE subclassifies the last three items into *lower* and *upper*. The use of the scale differs across studies in that some included patients *after acute hospital* admission and therefore included the initial high mortality group, whereas some included patients *after in-hospital rehabilitation admission*, and others included patients even later and without the initial high mortality. Either approach has limitations. Inclusion *after acute hospital admission* is usually accompanied by a high loss of follow-up because of the high incidence of refusal or unavailability of patients at follow-

Table 2: Large, multicentre cohort studies in high-income countries reporting on short-term mortality in adults with severe traumatic brain injury (Part A).

First author	Journal	Year of publication	Design	Inclusion criteria	Region	Inception period
Walder	J Neurotrauma	2013	Population-based	HAIS >3	Switzerland	2007–2010
Andelic – Norwegian Cohort	Neuroepidemiology	2012	Population-based	ICD-10 and GCS <9	Norway	2009–2010
Zygun	Can J Neurol Sci	2005	Population-based	ISS >11, GCS <9	Calgary (Canada)	1999–2002
Masson	J Trauma	2001	Population-based	HAIS >3	Aquitaine (France)	1996
Bouillon	Restor Neurol Neurosci	1999	Population-based	GCS <9 or HAIS >2	Cologne (Germany)	1990–1996
Bayen (PariS-TBI)	J Head Trauma Rehabil	2012	Inception cohort	GCS <9	Paris (France)	2005–2007
Andriessen	J Neurotrauma	2011	5 out of 11 trauma centres (POCON)	GCS <14 (ED)	Netherlands	2008–2008
Myburgh	J Trauma	2008	16 out of 21 trauma centres (ATBIS)	TBI admitted to ICU or died in ED/OR	Australia / New Zealand	2000
Leitgeb/Rosso/Rusnak	Wien Klin Wochenschr	2007	5 out of X* trauma centres°	GCS <9 (post-resuscitation)	Austria	1999–2004
Murray	Acta Neurochir	1999	67 out of X* trauma centres°	GCS <9 (neurosurgical unit)	Europe	1995

ATBIS = Australasian traumatic brain injury study; ED = emergency department; GCS = Glasgow Coma Score; HAIS = abbreviated Head Injury Score; ICD = International Classification of Diseases; ICU = intensive care unit; ISS = Injury Severity Score; OR = operating room; POCON = Prospective Observational COhort Neurotrauma
*X: unknown number of trauma centres per country / region

Table 3: Large, multicentre cohort studies in high-income countries reporting on short-term mortality in adults with severe traumatic brain injury (Part B).

First author	Youngest included patient	Mean, median* age (SD; IQR*)	Male gender (%)	Road traffic accidents (%)	Falls (%)	Mean, median* initial GCS (SD; IQR*)	No. with initial GCS <9 / no. of patients (%)	Mean median* ISS (SD, IQR*)	Prehospital data	Admission direct to trauma centre (%)	Mean, median* time between call and hospital arrival (min)	Early mortality (%)
Walder	16	55 (33–71)*	74.2	31.6	52.6	5 (3–14)*	508/921 (56.4)	25 (20–34)*	Y	71.9	46*	30.2 (14 d)°
Andelic – Norwegian Cohort	16	46.7 (21.6)	77	40	50	5.3 (2.0)	359/359 (100)	NA	N			29 (in-hospital)
Zygun	18	40 (20)	74.3	47	34	4 (3-7)*	242/242 (100)	25 (24–35)*	Y	92.2	68*	45 (in-hospital)°
Masson	Any	44 (22–72)*	71.4	48.3	41.8	NA	245/642 (38.2)	NA	N			30 (in-hospital)
Bouillon	Any	39 (NA)	71	56	31	6.8 (NA)	455/650 (70)	NA	Y		47	46.6 (in-hospital)°
Bayen	15	42 (20)	77	53	35	5 (2)	504/504 (100)	NA	N			49 (in-hospital)
Andriessen	16	47.3 (20.4)	70	51	49	4 (3-11)*	339/508 (66.7)	25 (18–36)*	(Y)	86		33.3 (in-hospital)
Myburgh	16	41.6 (19.6)	74.2	61.4	24.9	7 (3–12)*	363/635 (57.2)	26 (18–34)*	Y	56.4	63	18.1 (ICU mortality)
Leitgeb/Rosso/Rusnak	Any	48 (21)	72	44	41	5.8 (3.1)	492/492 (100)	27.2 (12.9)	Y	85	NA	31.6 (ICU mortality)
Murray	16	41 (20)	73	52	11	NA	583/1005 (58.0)	NA	(Y)	45	45*	31 (6 months)

GCS = Glagow Coma Score; IQR = interquartile range; ISS = Injury Severity Score; N = no; NA = not available; SD = standard deviation; Y = yes
° including prehospital period

up in population-based studies of neurotrauma. This refusal and unavailability after acute hospital discharge is often based on alcoholism, depression and low socioeconomic status [22]. The resulting high attrition rate may skew the data distribution on the items *severe disability*, *moderate disability* and *good recovery*. The *late inclusion* of TBI survivors facilitates an improved follow-up; however, without the analysis of the initial distribution of surviving and not surviving patients, results may be skewed as well.

Large multicentre cohort studies, that include individuals with severe TBI and that report short-term disability independently of the inclusion criteria and the time of inclusion, report decreased disability in the first year after TBI (table 4) [9, 13, 14, 16, 17, 23]. A comparison across studies is difficult because of differences in study design, analysis, and use and reporting of GOS(E) results. Interestingly, the Swiss population-based study, which included the oldest population, observed a decrease in reported disability over time as well. This similarity in decrease may suggest adequate quality of rehabilitative care in Switzerland – even for elderly patients.

Short-term outcome of elderly traumatic brain injury patients

The definition of elderly or geriatric patients lacks homogeneity. There is a certain consensus that patients with neurotrauma who are aged >65 years are considered elderly patients [24, 25]. Using this definition, we observed a high proportion of elderly patients with severe TBI (35%) in Switzerland. In comparison with patients ≤65 years, pa-

tients >65 years showed a higher incidence (22/100,000/ year), a higher GCS at hospital admission (8) [3–14], but similar abnormal pupil reaction and similar HAIS compared with patients ≤65 years (i.e., comparable TBI severity) [9]. Death rate at 14 days was higher in older patients (41%), and consciousness at 14 days assessed with the GCS was similar across the two age groups. Normed GOSE data in older Swiss patients are presently not available; however, it has been suggested that GOSE scores are lower for older than younger patients. Severe TBI has rarely been investigated in older patients, and the few studies that did this, have reported incomplete data (table 5) [8–10, 25, 26]. Nevertheless, those few studies all reported: (a) a high incidence rate; (b) falls as the main trauma mechanism; and (c) a high death rate in older patients with neurotrauma.

Implications for further quality improvement programmes in Switzerland

There is a debate about the decreasing incidence of severe TBI in high-income countries [12]. An argument in favour of a decrease in incidence may be improved road safety and/or other safety-related interventions. An argument against a decrease in incidence may be the increasing age of the population that is associated with more falls. The Swiss Trauma Register, which will include similar standardised data, may be able to answer this question in the near future. We suspect that the incidence of severe TBI will increase in relation to the demographic increase in the eld-

Table 4: Large, multicentre cohort studies in high-income countries reporting on short-term disability of adults with severe traumatic brain injury.

First author	Journal	Year of publication	Inclusion criteria	Region	Mean, median* age (SD; IQR*)	Falls (%)	Mean, median* initial GCS (SD; IQR*)	Mean median* ISS (SD, IQR*)	Mean, median*or % GOSE° (SD, IQR*) at x months
Walder	J Neurotrauma	2013	HAIS>3	Switzerland	55 (33–71)*	52.6	5 (3-14)*	25 (20–34)*	5 (3–7) at 3 months* 6 (4–8) at 6 months*
Anke - Norwegian Cohort	J Head Trauma Rehabil	2015	ICD-10 and GCS <9	Norway	40.1 (18.6)	44	NA	28.1 (11.7)	1:NA, 2:3, 3:17, 4:7, 5:39, 6:19, 7:7, 8:8 at 3 months 1:4, 2:2, 3:9, 4:4, 5:18, 6:31, 7:14, 8:22 at 12 months
Bayen (PariS-TBI)	J Head Trauma Rehabil	2012	GCS <9	Paris (France)	42 (20)	35	5 (2)	NA	5 (1.2) at 12 months
Andriessen	J Neurotrauma	2011	GCS <14 (ED)	Netherlands	47.3 (20.4)	49	4 (3-11)*	25 (18–36)*	Severe TBI: 1:NA, 2:1, 3:14, 4:13, 5:31, 6:31, 7:18, 8:20 at 6 months Severe TBI: 1:NA, 2:1, 3:12, 4:13, 5:24, 6:29, 7:29, 8:22 at 12 months Moderate TBI: 1:NA, 2:0, 3:7, 4:11, 5:15, 6:20, 7:14, 8:33 at 6 months Moderate TBI: 1:NA, 2:0, 3:4, 4:15, 5:13, 6:12, 7:14, 8:41 at 12 months
Myburgh	J Trauma	2008	TBI admitted to ICU or died in ED/OR	Australia / New Zealand	41.6 (19.6)	24.9	7 (3-12)*	26 (18–34)*	1:24, 2:1, 3:12, 4:8, 5:12, 6:23, 7:10, 8:10 at 6 months 1:27, 2:1, 3:8, 4:5, 5:8, 6:20, 7:16, 8:15 at 12 months
Murray	Acta Neurochir	1999	GCS <9 (neurosurgical unit)	Europe	41 (20)	11	NA	NA	GOS§: 1:31, 2:3, 3:16; 4:20, 5:31 at 6 months

ED = emergency department; GCS = Glasgow Coma Score; GOSE = Glasgow Outcome Scale (extended) HAIS = abbreviated Head Injury Score; ICD = International Classification of Diseases; ICU = intensive care unit; IQR = interquartile range; NA = not available; OR = operating room; SD = standard deviation; TBI = traumatic brain injury

°1 = death, 2 = vegetative state, 3 = lower severe, 4 =upper severe, 5 = lower moderate, 6 = upper moderate disability, 7 = lower good recovery, 8 = higher good recovery

erly population, a trend that has previously been reported in Canada [27].

Mortality after severe trauma and severe TBI is associated with trauma centre patient volume: the higher the volume, the lower the mortality [28]. US trauma centres were considered "high volume" if they had more than 160 patients with moderate and severe TBI (expected mortality >15%) per year [29]. A high-volume effect has also been observed in Taiwan, although with lower annual numbers (>33 patients with TBI needing surgery) [30]. Based on these international data, some Swiss trauma centres would not be considered high-volume trauma centres and may thus have less favourable outcomes. Potentially, the increase in mortality in low volume centres is not related to healthcare *per se*, but to structural problems: Many patients with neurotrauma are admitted outside usual business hours and days, and thus require twenty-four/seven coverage with highly competent medical staff at night and during weekends, which may be difficult to realise in low-volume trauma centres. However, reduced staffing in trauma centres impacts upon outcome [31].

There is evidence that the speed of functional recovery depends on early and intensive neurorehabilitation [26, 32, 33]. Discharge after inpatient and/or outpatient neurorehabilitation should be based on objective discharge criteria including cognitive functioning [34]. However, at least in US rehabilitation centres, huge variability in risk-adjusted centre-specific disability outcomes can be observed by use of the Disability Rating Scale [35]. Normally, high centre-specific outcome variability is associated with care quality differences, which can be improved. However, on the basis of the large number of rehabilitation centres in Switzerland where severe TBI patients are actually treated, and the fact that the time-span between discharge from acute care to rehabilitation admission is different across centres, we suspect that centre-specific outcome variability may be present in Switzerland as well. Further scientific investigations are clearly indicated to define the optimal post-acute care pathway for neurotrauma in Switzerland. These potentially more managerial investigations may include: (a) efficiency interventions with the use of a uniform documentation from acute care to post-acute care; (b) comparative interventions with different numbers of rehabilitative therapists; (c) different rehabilitation intensity per age-specific patient group; and (d) efficiency interventions with the use of uniform and minimal discharge criteria.

We see room for improvement not only in acute care and rehabilitation separately, but also in the interaction between acute care and rehabilitation. Improved clinical pathways from prehospital care to rehabilitation, more effective resource allocation, and decreased health and economic costs are desirable and possible. Currently, the estimated TBI costs for the Swiss Accident Insurance (SUVA) alone reach 170 million CHF per year for moderate to severe TBI (press release 2014). Since SUVA mainly insures individuals who are currently employed, TBI costs for Switzerland are estimated to be significantly higher than the reported SUVA data.

It is evident that populations in high-income countries – including Switzerland – are ageing. Older age in turn is associated with an increased risk of falls from low heights [36] and thus a higher probability of neurotrauma. These older populations with severe TBI show comorbidities with illnesses that need permanent drugs including drugs with increased risk of bleeding (e.g, phenprocoumon, warfarin). In neurotrauma anticoagulation aggravates the initial lesions as a result of space-occupying intracranial bleeding. In elderly TBI patients with brain atrophy and low energy impact, however, there could be a time window for surgical and drug interventions before space-occupying haematomas occur. This hypothesis is supported by our observation that initial GCS scores in elderly patients were quite high. In other words, if elderly patients with previously greater brain atrophy are exposed to a TBI, the bleeding will not immediately occupy space (reflected by higher GCS at scene or at hospital admission) compared with younger patients (without premorbid brain atrophy). As a result, this observed unique time window among elderly patients should be used for interventions before major cerebral injury occurs.

The prehospital and early in-hospital pathway for elderly patients with TBI should include diagnostic measures that allow optimal use of this unique opportunity. Furthermore, and related to the prolonged recovery process in elderly patients, specific in-hospital care (for instance, in intermediate care units) and adapted rehabilitation programmes should be investigated. Interdisciplinary, standardised pathways including healthcare professionals in acute care, as

Table 5: Large, multicentre cohort studies in high-income countries reporting on short-term mortality in elderly adults with traumatic brain injury.

First author	Journal	Year of publication	Inclusion criteria	Region	Incidence in elderly (>65 years)	Female gender (%)	Falls (%)	Mean, median* initial GCS (SD)	Mean, median* ISS (SD)	Early mortality (%)
Walder	J Neurotrauma	2013	HAIS >3	Switzerland	22.4 (34.7% of database)	71.2	75.6	8 (3–14)	25 (20–29)	40.9 (14 days)
Andelic - Norwegian Cohort	Neuroepidemiology	2012	ICD-10 and GCS <9	Norway	NA	Always more males	More falls >45y	NA	NA	About 50
Zygun	Can J Neurol Sci	2005	ISS >11, GCS <9	Calgary (Canada)	30 (>75 y)	Always more males	NA	NA	NA	NA
Masson	J Trauma	2001	HAIS >3	Aquitaine (France)	NA	Always more males	More falls >45 y	NA	NA	Abrupt increase >70 y
Patel	Acta Neurochir	2010	HAIS >2 and GCS <9	England and Wales	16% of TBI in register	36–53	49–54	mGCS 1–3	25	78.5 (3 months)

GCS = Glasgow Coma Score; HAIS = abbreviated Head Injury Score; ICD = International Classification of Diseases; ISS = Injury Severity Score; NA = not available; SD = standard deviation; TBI = traumatic brain injury

well as the combined work of rehabilitation specialists for geriatrics, neurology and neuropsychology may be the most promising future for this specific population group. Based on our data, we suspect that elderly patients receive different rehabilitation compared with younger patients (either no rehabilitation or qualitatively relatively lower rehabilitation). A general behavioural change in healthcare providers towards elderly trauma patients may be needed to counter lower care intensity, which in turn may so far have been associated with an increased death rate [37].

Because the incidence of severe TBI in elderly patients is increasing, and is probably even increasing at a faster rate than the ageing population itself [36], effective preventive measures are required. Given that falls at home and anticoagulation or antiaggregation are causal factors in a high number of these patients, fall prevention (e.g., strength and balance training [38]) and possibly modifications of the home [39], combined with drug adaptation [40] could be possible approaches to reducing and possibly minimising the occurrence of TBI in the elderly. However, further research is required to confirm these potential preventive strategies.

Conclusions

Severe neurotrauma is still a challenge, even in high-income countries. The probability of unfavourable short-term outcome after severe neurotrauma continues to be high and is, at least partially, related to an increased proportion of elderly patients. Healthcare systems need to provide high standard emergency and trauma care followed by comprehensive critical care and seamless transitions to timely and aggressive (neuro-)rehabilitation, in order to be able to send patients home with the best possible functional recovery. Procedural and structural improvements can be achieved with a system that includes interdisciplinary teams: All elements of care have to interact closely (i.e., efficient clinical pathways) to provide patients with the best possible outcomes. Based on our data from – and experience with – the Swiss cohort with severe TBI, quality of care in Switzerland can be further improved.

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References

1 Ponsford J, Janzen S, McIntyre A, Bayley M, Velikonja D, Tate R. INCOG recommendations for management of cognition following traumatic brain injury, part I: posttraumatic amnesia/delirium. J Head Trauma Rehabil. 2014;29(4):307–20.

2 Feigin VL, Theadom A, Barker-Collo S, Starkey NJ, McPherson K, Kahan M, et al. Incidence of traumatic brain injury in New Zealand: a population-based study. Lancet Neurol. 2013;12(1):53–64.

3 Winter Y, Oertel WH, Dodel R. Is there underfunding in brain research? The UK research expenditure. Eur J Neurol. 2012;19(1):4–5.

4 Shivaji T, Lee A, Dougall N, McMillan T, Stark C. The epidemiology of hospital treated traumatic brain injury in Scotland. BMC Neurol. 2014;14(1):2.

5 Zuercher M, Ummenhofer W, Baltussen A, Walder B. The use of Glasgow Coma Scale in injury assessment: a critical review. Brain Inj. 2009;23(5):371–84. Epub 2009/05/02.

6 Andelic N, Anke A, Skandsen T, Sigurdardottir S, Sandhaug M, Ader T, et al. Incidence of hospital-admitted severe traumatic brain injury and in-hospital fatality in Norway: a national cohort study. Neuroepidemiology. 2012;38(4):259–67. Epub 2012/06/09.

7 Bouillon B, Raum M, Fach H, Buchheister B, Lefering R, Menzel J, et al. The incidence and outcome of severe brain trauma – Design and first results of an epidemiological study in an urban area. Restor Neurol Neurosci. 1999;14(2):85–92. Epub 1999/01/01.

8 Masson F, Thicoipe M, Aye P, Mokni T, Senjean P, Schmitt V, et al. Epidemiology of severe brain injuries: a prospective population-based study. J Trauma. 2001;51(3):481–9. Epub 2001/09/06.

9 Walder B, Haller G, Rebetez MM, Delhumeau C, Bottequin E, Haller CS, et al. Severe traumatic brain injury in a high-income country: An epidemiological study. J Neurotrauma. 2013;30:1934–42. Epub 2013/07/05.

10 Zygun DA, Laupland KB, Hader WJ, Kortbeek JB, Findlay C, Doig CJ, et al. Severe traumatic brain injury in a large Canadian health region. Can J Neurol Sci. 2005;32(1):87–92. Epub 2005/04/14.

11 Mutschler M, Nienaber U, Wafaisade A, Brockamp T, Probst C, Paffrath T, et al. The impact of severe traumatic brain injury on a novel base deficit-based classification of hypovolemic shock. Scand J Trauma Resusc Emerg Med. 2014;22(1):28.

12 Stein SC, Georgoff P, Meghan S, Mizra K, Sonnad SS. 150 years of treating severe traumatic brain injury: a systematic review of progress in mortality. J Neurotrauma. 2010;27(7):1343–53. Epub 2010/04/16.

13 Andriessen TM, Horn J, Franschman G, van der Naalt J, Haitsma I, Jacobs B, et al. Epidemiology, severity classification, and outcome of moderate and severe traumatic brain injury: a prospective multicenter study. J Neurotrauma. 2011;28(10):2019–31. Epub 2011/07/27.

14 Bayen E, Pradat-Diehl P, Jourdan C, Ghout I, Bosserelle V, Azerad S, et al. Predictors of Informal Care Burden 1 Year After a Severe Traumatic Brain Injury: Results From the PariS-TBI study. J Head Trauma Rehabil. 2012; [Epub ahead of print]. Epub 2012/06/14.

15 Leitgeb J, Erb K, Mauritz W, Janciak I, Wilbacher I, Rusnak M. Severe traumatic brain injury in Austria V: CT findings and surgical management. Wien Klin Wochenschr. 2007;119(1–2):56–63. Epub 2007/02/24.

16 Murray GD, Teasdale GM, Braakman R, Cohadon F, Dearden M, Iannotti F, et al. The European Brain Injury Consortium survey of head injuries. Acta Neurochir (Wien). 1999;141(3):223–36. Epub 1999/04/24.

17 Myburgh JA, Cooper DJ, Finfer SR, Venkatesh B, Jones D, Higgins A, et al. Epidemiology and 12-month outcomes from traumatic brain injury in australia and new zealand. J Trauma. 2008;64(4):854–62. Epub 2008/04/12.

18 Ross SR, Millis SR, Rosenthal M. Neuropsychological prediction of psychosocial outcome after traumatic brain injury. Appl Neuropsychol. 1997;4(3):165–70.

19 Rosso A, Brazinova A, Janciak I, Wilbacher I, Rusnak M, Mauritz W. Severe traumatic brain injury in Austria II: epidemiology of hospital admissions. Wien Klin Wochenschr. 2007;119(1–2):29–34. Epub 2007/02/24.

20 Mushkudiani NA, Engel DC, Steyerberg EW, Butcher I, Lu J, Marmarou A, et al. Prognostic value of demographic characteristics in traumatic brain injury: results from the IMPACT study. J Neurotrauma. 2007;24(2):259–69. Epub 2007/03/23.

21 Perel P, Arango M, Clayton T, Edwards P, Komolafe E, Poccock S, et al. Predicting outcome after traumatic brain injury: practical prognostic models based on large cohort of international patients. BMJ. 2008;336(7641):425–9. Epub 2008/02/14.

22 Jourdan C, Bayen E, Bosserelle V, Azerad S, Genet F, Fermanian C, et al. Referral to rehabilitation after severe traumatic brain injury: results from the PariS-TBI Study. Neurorehabil Neural Repair. 2013;27(1):35–44. Epub 2012/03/31.

23 Anke A, Andelic N, Skandsen T, Knoph R, Ader T, Manskow U, et al. Functional Recovery and Life Satisfaction in the First Year After Severe Traumatic Brain Injury: A Prospective Multicenter Study of a Norwegian National Cohort. J Head Trauma Rehabil. 2014.

24 De Bonis P, Pompucci A, Mangiola A, Paternoster G, Festa R, Nucci CG, et al. Decompressive craniectomy for elderly patients with traumatic brain injury: it's probably not worth the while. J Neurotrauma. 2011;28(10):2043–8. Epub 2011/06/07.

25 Patel HC, Bouamra O, Woodford M, Yates DW, Lecky FE. Clinical article: mortality associated with severe head injury in the elderly. Acta Neurochir (Wien). 2010;152(8):1353–7. Epub 2010/05/04.

26 Andelic N, Bautz-Holter E, Ronning P, Olafsen K, Sigurdardottir S, Schanke A-K, et al. Does an early onset and continuous chain of rehabilitation improve the long-term functional outcome of patients with severe traumatic brain injury? J Neurotrauma. 2012;29(1):66–74.

27 Cadotte DW, Vachhrajani S, Pirouzmand F. The epidemiological trends of head injury in the largest Canadian adult trauma center from 1986 to 2007. J Neurosurg. 2011;114(6):1502–9. Epub 2011/02/01.

28 Minei JP, Fabian TC, Guffey DM, Newgard CD, Bulger EM, Brasel KJ, et al. Increased trauma center volume is associated with improved survival after severe injury: results of a Resuscitation Outcomes Consortium study. Ann Surg. 2014;260(3):456–64; discussion 64-5. Epub 2014/08/15.

29 Celso B, Tepas J, Langland-Orban B, Pracht E, Papa L, Lottenberg L, et al. A systematic review and meta-analysis comparing outcome of severely injured patients treated in trauma centers following the establishment of trauma systems. J Trauma. 2006;60(2):371–8. Epub 2006/03/02.

30 Shi H-Y, Hwang S-L, Lee I-C, Chen I-T, Lee K-T, Lin C-L. Trends and outcome predictors after traumatic brain injury surgery: a nationwide population-based study in Taiwan: Clinical article. J Neurosurg. 2014;121(6):1323–30.

31 Schneider EB, Hirani SA, Hambridge HL, Haut ER, Carlini AR, Castillo RC, et al. Beating the weekend trend: Increased mortality in older adult traumatic brain injury (TBI) patients admitted on weekends. J Surg Res. 2012;177(2):295–300. Epub 2012/07/17.

32 Godbolt AK, Cancelliere C, Hincapié CA, Marras C, Boyle E, Kristman VL, et al. Systematic review of the risk of dementia and chronic cognitive impairment after mild traumatic brain injury: results of the International Collaboration on Mild Traumatic Brain Injury Prognosis. Arch Phys Med Rehabil. 2014;95(3):S245–S56.

33 Zhu X, Poon W, Chan CC, Chan SS. Does intensive rehabilitation improve the functional outcome of patients with traumatic brain injury (TBI)? A randomized controlled trial. Brain injury. 2007;21(7):681–90.

34 Leon-Carrion J, Dominguez-Morales MR, Barroso y Martin JM, Leon-Dominguez U. Recovery of cognitive function during comprehensive rehabilitation after severe traumatic brain injury. J Rehabil Med. 2012;44(6):505–11. Epub 2012/06/05.

35 Dahdah MN, Barisa MT, Schmidt K, Barnes SA, Dubiel R, Dunklin C, et al. Comparative effectiveness of traumatic brain injury rehabilitation: differential outcomes across TBI model systems centers. J Head Trauma Rehabil. 2014;29(5):451–9.

36 Harvey LA, Close JC. Traumatic brain injury in older adults: characteristics, causes and consequences. Injury. 2012;43(11):1821–6. Epub 2012/08/14.

37 Thompson HJ, Rivara FP, Jurkovich GJ, Wang J, Nathens AB, MacKenzie EJ. Evaluation of the effect of intensity of care on mortality after traumatic brain injury. Crit Care Med. 2008;36(1):282–90. Epub 2007/11/17.

38 Uusi-Rasi K, Patil R, Karinkanta S, Kannus P, Tokola K, Lamberg-Allardt C, et al. Exercise and vitamin D in fall prevention among older women: a randomized clinical trial. JAMA internal medicine. 2015;175(5):703–11.

39 Keall MD, Pierse N, Howden-Chapman P, Cunningham C, Cunningham M, Guria J, et al. Home modifications to reduce injuries from falls in the home injury prevention intervention (HIPI) study: a cluster-randomised controlled trial. Lancet. 2015;385(9964):231–8. Epub 2014/09/27.

40 Laflamme L, Monarrez-Espino J, Johnell K, Elling B, Moller J. Type, number or both? A population-based matched case-control study on the risk of fall injuries among older people and number of medications beyond fall-inducing drugs. PLoS One. 2015;10(3):e0123390. Epub 2015/03/31.