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TRAUMATIC BRAIN INJURY AND DEMENTIA (K WANG, SECTION EDITOR)

Geriatric Traumatic Brain Injury in Hungary and Eastern Europe

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Abstract While the incidence of traumatic brain injury (TBI) is decreasing in the young, active population, injuries are getting more frequent among the elderly; as the geriatric population is in a constant rise and the relative cost of care is particularly high in this group of patients, the economic burden of TBI does not decline. This review is aimed to identify predisposing factors and characteristic features of geriatric brain injury, primarily focusing on the comparison between Eastern and Western European countries. While economically each of these is a high- or middle-income country, the differences in mortality and morbidity, approaches, and policies applied by health care providers are substantial. On the basis of the disappointing outcome results in Eastern Europe, one may conclude that therapeutic guidelines defined on the basis of the "Western experience" should only be applied in conjunction with a systematic reorganization of health care in Eastern Europe.

Keywords Brain injury · Trauma · Elderly · Geriatric · Outcome prediction · Glasgow Coma Scale · IMPACT database · Epidemiology · Guideline · Eastern Europe · Hungary

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Introduction

Traumatic brain injury (TBI) is the leading cause of death and disability in the first four decades and estimated to become the third most frequent cause of morbidity in 10 years. The worldwide prevalence of TBI of various severities is about 1,000/100,000 inhabitants; in the United States alone more than 5 million people live with disabilities following TBI [1, 2].

Most of the efforts in TBI research and care have been focused on the socioeconomic burden TBI puts on societies due to its predominance among young, active individuals.

Preventive measures such as increasing road traffic safety as well as aggressive medical/intensive care unit (ICU) treatment of victims of TBI were primarily aimed to reduce mortality in the active population. While these efforts resulted in a decreased occurrence and mortality of TBI among young individuals, a solid and constant rise of incidence was detected in the elderly.

Such an increased incidence is primarily explained by the rapid aging of populations: in Canada in the last four decades, life expectancy has increased with more than 10 years; thereby the population over age 65 years will be duplicated in the forthcoming two decades [3••].

The estimated incidence of TBI in the elderly is about 200/100,000 inhabitants, which is about twice as much as

that of the general population. As Ferrel et al. [4] point out, this number can be higher because many of the falls (the leading cause of injury in the elderly) occur in nursing homes and most probably remain unreported.

The growing magnitude of geriatric head injury raises various questions and concerns including efficacy and cost-efficiency issues, the problem of targeted and tailored therapy based on pathophysiological traits of the elderly, as well as the withdrawal of care.

This review intends to provide a comprehensive, meticulous analysis of geriatric head injury primarily focusing on special features associated with the care provided in Eastern European countries.

Why Does Geriatric Brain Injury Differ?

The definition of geriatric brain injury is somewhat arbitrary; most reports refer to elderly patients over age 65 years and some identify a group of the "super elderly" over age 80 years [3••, 5].

Most researchers think that geriatric TBI (gTBI) should be considered a separate entity because of its unique features. Most of the publications report on worse outcome in this patient population [4, 6–8, 9••] while some claim that results can approximate that of younger individuals [10••].

The population of gTBI patients is unique from various aspects. While the frequency of injury is almost double in comparison with the general population, with increasing age the male predominance is disappearing (partially, due to the simultaneous, stepwise increase in the proportion of females in the geriatric population) [8, 11, 12].

Incidence of TBI is higher, primarily due to physiological alterations associated with aging. Merely, the organs of senses do not function properly; thereby, not only the perception but also the reaction time is altered. Medications that are frequently consumed for hypertension, Parkinson's disease, and depression produce side effects that make this population more prone to injury, causing dizziness, vertigo, and blackouts [3••, 13, 14•].

This is one explanation for the more frequent occurrence of falls among the elderly while in the younger population motor vehicular accidents are dominating [15].

Once the injury occurs, physiological alterations associated with aging also define the faith of the patient as well as the characteristics of TBI.

Falls predominantly lead to inertial, deceleration type of diffuse brain injury conjoined by focal hits (impact-injury) [4, 5, 11].

The dura is rather tightly attached to the tabula interna of the skull; thereby, extradural hematomas are less frequent while cerebral atrophy leads to increased stretch of the bridging veins, making them more prone to rupture upon deceleration ending up in more common accordance of subdural collections/hematomas [4, 16].

Engorgement of traumatically evoked intracranial hematomas can be explained by frequent use of medications targeting components of the hemostatic machinery. Warfarin and coumarin treatment is associated with worse outcome but also inhibitors of platelet aggregation have a reputation for exaggerating intracranial bleedings [17, 18].

Rigidity of the cervical spine makes the occipitocervical junction more prone to injury; thereby, upper cervical (C) spine injuries relatively more frequently accompany gTBI than subaxial C-spine fractures [19, 20]. Similarly reduced flexibility of the cranial-cranio-cervical structures as well as reduced turgor of the soft tissues around, including that of the cervical muscles, may account for the surprisingly high incidence of positive computed tomography (CT) findings, reaching to more than 10 % of minor head injuries in the elderly [21].

Not surprisingly, current diagnostic and management protocols advise more liberal use of CT, particularly in the elderly population [19, 22, 23].

While generally the reduced physiological reserve in association with (and also due to) comorbidities diminishes the chances of survival and quality of life following gTBI [24, 25], at the subcellular level, a major drawback of the advanced age is the decreased capacity to scavenge mediators of the oxidative stress [16].

As it has been alluded to before, generally gTBI is believed to be associated with poor outcome or, at least, a reduced chance for good functional and neurocognitive results in comparison with TBI occurring in the general population. However, recent studies have pointed out that state-of-the-art neurosurgical care including multimodal monitoring at the neurosurgical ICU can make a difference, and the outcome of gTBI can be comparable with that of younger patients [9••, 10••, 26, 27].

Specifically, Lau et al. [10••] assessed survival of gTBI patients over age 80 years who have undergone emergency craniotomies and found remarkably similar chances to younger TBI victims for these "super elderly" patients to survive the injury as well as to reach the premorbid baseline quality of life.

The Price of Extended Lifespan

The investigations here described harbor a critical element that is the cost-benefit ratio.

While the scientific society as well as clinicians are dedicated and devoted to provide the best possible care worldwide we should be candid and admit that decisions about treatment intensity are affected by cultural and economic differences not necessarily reflected in official

therapeutic guidelines and protocols. Such an approach can appear in under-triage to larger centers, withheld or withdrawal of care, or simply by noncompliance with guidelines and/or extreme shift in age-related mortality figures [26–29]. This is particularly true for countries and health care systems harboring limited resources (vide infra).

Via a detailed review of the literature, one may identify the "extremes" of survival rate and quality-of-life expectations ranging from 8 % survival rate in the general geriatric trauma population [26, 27] to series with outcome results comparable to that of the general population [10••].

Due to the heterogeneity of this group of patients, it is rather difficult to identify those factors facilitating better outcome in gTBI; nevertheless, the role of age within this subset of head-injured patients is rather obvious. Some epidemiological studies characterized that age has a longitudinal effect on survival [30].

Nevertheless, on the basis of various trials, it is hard to draw a clear age zone indicative of poor outcome and extreme costs associated with therapeutic efforts. Yet, a relative well-delineated difference appears between those who have sustained their TBI under ages 70–75 years and the ones over this age zone.

Stocchetti et al. [9••] recently reported on a database of 1366 patients between 19 and 94 years of age where the probability of unfavorable outcome was six times higher above the age of 59 years than in the younger population. Their "cut off point" appeared to be 69 years, where favorable outcome was still possible without extreme additional burden of severely disabled survivors.

When Bouras et al. [31] stratified their 1929 elderly patients into three groups by age, they have found that the group over 75 years did not benefit from ICU treatment, and had a significantly lower chance to survive the surgical intervention [31]. Utomo and coworkers [32••] also found that gTBI patients had significantly worse outcome over the age of 75 years.

Although the role of age is obviously important in outcome prediction we do not have any reason to decide about the intensity of care and the activity of the caregivers merely on the basis of this very information. Although Leblanc et al. [33] in a retrospective analysis of a Canadian cohort of 684 TBI patients aged 60–99 years reported on significantly worse outcome in comparison with younger patients regardless of injury severity, still more than 80 % of survivors of mild and 50 % of severe TBI returned home or have been transferred to rehabilitation following the acute care.

Similar figures are well known for the geriatric population in the general trauma literature [28], also highlighting the importance of active multidisciplinary treatment of the elderly.

In a recent paper assessing the outcome of gTBI patients over the age of 65 years and a first available Glasgow Coma Score (GCS) of 4 or less, Brazinova et al. highlighted that favorable outcome in this subgroup of patients is still feasible: 11 % of their patients reached this level at 12 months postinjury [34••].

Nevertheless, with rising age, the cost efficiency of treatment is obviously decreasing. The results that could be achieved in severely head-injured patients over age 65 years can be very disappointing: in the report of Utomo et al. [32••], none of the patients under a GCS of less than 9 had a favorable outcome at 6 months postinjury and most of them passed away.

The remarkable surgical results by Lau et al. [10••] alluded to before in the population over age 80 years were achieved via significantly more frequent and serious complications including infections and longer hospital stay in a setting where direct cost associated with craniotomy for TBI itself costs more than $15,000 USD [10••].

Outcome Prediction in Geriatric Traumatic Brain Injury

Identification of independent predictors of outcome in gTBI is of ample importance not only to aid informing and consenting the relatives but also to serve quality control issues that is the audit of care. To this end, in the general trauma literature, the Injury Severity Score (ISS) proved to be a significant predictor of outcome in the geriatric population [24, 35].

Similarly, the GCS, and particularly its motor score, is closely associated with outcome, a finding also corroborated at gTBI [3••, 32••]. Data from general trauma care (in a series where about 80 % of the enrolled cases were head injured) indicate C-spine injury to be an independent predictor of poor outcome [3••].

Another study found that poor outcome following gTBI was associated with the actual age, GCS, and injury type while patients under 75 years and/or with a systolic blood pressure of 131–150 mmHg had a significantly higher chance for favorable outcome [32••].

Brazinova et al. [34••] identified female sex, at least partially open basal cisterns, less severe injury, intracranial pressure (ICP) monitoring, and surgery to be associated with favorable outcome in gTBI of extreme severity (first available GCS under 5) [34••].

Of the premorbid conditions, the issue of altered hemostasis is of ample importance, a problem primarily associated with medications frequently used for the elderly [36, 37•].

Current consensus in the literature is that regardless of injury severity, prognostic factors should be used to aid decision making and consenting, but individual decisions on treatment and particularly withdrawal of care should not be justified exclusively on the basis of prognostic factors, mainly because we are far away from stone-carved guidelines in this matter.

Traumatic Brain Injury in Eastern Europe: Neurotrauma Care

Although spiritually and traditionally most of the Eastern European countries, including Hungary, consider themselves as historic building blocks of Europe, these countries are definitely handicapped as far as their health care system is considered.

While most of them do belong to high- or middle-income countries, their health care system is rather characterized by features of lower-middle income or low income countries.

A major cause of this is that the health care sector itself had not been included into negotiations as a topic before these countries have joined the united Europe.

In this region, neurotrauma care is traditionally characterized by decisions primarily based on expert opinion while scientific evidence-based guidelines, even if they are distributed, are not necessarily welcome and particularly not followed by health care providers. This leads to inequality of care and an unacceptably high mortality and morbidity of TBI that, because of the lack of any central audit of care, remains unrecognized and unpunished [38–41].

Most of these countries are in the beginning of reorganization/restructuring their health care systems, including emergency care as well as organization of the trauma system. To this end, the number of secondary or even tertiary transfers, limited availability of facilities dedicated to neurorehabilitation, as well as a lack of the audit of care and application of quality assurance visits and checks are considered burning problems [39, 42].

Due to these features, the region provides an excellent opportunity to test the efficacy of evidence-based guidelines to make a change in the outcome of TBI. This case was elegantly demonstrated with the TBI-Trac program headed by Jamshid Ghajar and founded by the Soros Foundation in the late 1990s. The success of this program itself led to a change in the field of neurotrauma in Eastern Europe, facilitating the dissemination of guidelines, spreading the word against the hopelessness of head injury, and recruiting young neurosurgeons to make a difference in neurotrauma care [43, 44].

Traumatic Brain Injury in Eastern Europe: The Actual Care

Probably due to the difficulties alluded to before, only a handful of epidemiological reports and reviews address the burden of TBI on societies in Eastern Europe and data regarding gTBI are particularly scant.

In Slovenia, the annual death toll of TBI is about 244/2 million, with 6205 hospitalizations, and the ratio of mild to moderate to severe TBI is about 80:15:5, respectively [45•] .

In Hungary, results extrapolated from a 3-month prospective data collection indicate 14,000 admissions annually, with 71.3 % mild, 19.4 % moderate, and 9.4 % severe TBI cases [39].

In Latvia, the incidence of moderate TBI to severe TBI is about 8 per 10,000 inhabitants; these two groups constitute more than 30 % of all TBI cases [43].

The most detailed research on TBI epidemiology in Eastern Europe has been conducted by the International Neurotrauma Research Organization (INRO) [42]. This seminal work compared TBI care in Austria, a "high-income" (HI) country, Slovakia and Croatia as "upper middle income" countries, and Bosnia-Herzegovina and the Former Yugoslav Republic of Macedonia considered "lower middle income" (LMI) countries. The authors claim that chances for application of guidelines (such as obeying the indications for ICP monitoring) decrease, while chances for violation of therapeutic standards (such as steroid use for TBI) increase with decreasing wealth. Similarly, the chances for serious complications, particularly those of infections as well as odds for considerable percentage of delayed mortality increase with poverty. The actual mortality proved to be more than 13 % above the "expected" rate in these LMI countries.

Unfortunately, this study also did not provide details on the mortality rate of the elderly, although the authors state that exclusion of cases with GCS 3 and over 65 years of age would have reduced the mortality from 42 %–55 % to around 20 %. These mortality figures are quite similar to those defined in the Hungarian prospective data collection (vide infra).

An intriguing finding of this study was the inequality of care, which has already been described in an analysis of patients receiving treatment for subdural hematoma in Hungary between various regions of the country [38]. While in the Hungarian analysis the significant between-center difference reaching 2.5-fold in favorable outcome was primarily due to substantially different extent of application of therapeutic guidelines and protocols, the INRO paper explained between-country differences with economic reasons.

Inequality of care has been described previously in Western Europe as well, yet differences appeared significant only in comparison with US outcome data. As Mauritz et al. [42] point out, this must be due to the fact that Hukkelhoven et al.'s [46] data exclusively derived from HI countries.

More recent studies also indicate that inequality of TBI care could be detected in an analysis of European and US centers too, but with a far pronounced difference in the former region (3.3-fold difference in the odds of unfavorable outcome between the centers in Europe versus 2.4 in the US) [47•].

Traumatic Brain Injury in Hungary: Emphasis on Geriatric Care

In the past decade, three epidemiological surveys analyzed the care of the head injured in Hungary revealing strikingly

similar results to the previously detailed studies that have involved Eastern European cases [38–40]. The most comprehensive of these investigations utilized a nationwide network of study coordinators and controlled enrollment with feedback from the National Insurance Service [39]. On the basis of this information, the authors achieved coverage of close to 80 % of all TBI patients enrolled in a 3-month period in the country. In all, 267 cases were considered where post-resuscitation GCS was under 9 on admission (severe TBI [sTBI]) or the patient deteriorated to reach the criteria of sTBI.

The other relevant source of information is the Pécs Severe TBI Database (sTBID) representing a comprehensive data repository on all patients consecutively admitted to the Department of Neurosurgery of Pécs University. This repository contained data elements from 305 TBI patients admitted between July 2002 and December 2008 either having post-resuscitation GCS under 9 on admission or deteriorating to meet the criteria of sTBI.

It is of note that none of these sources excluded cases with blown pupils and/or GCS 3.

We have identified 70 patients belonging to the "elderly" and 23 to the "super elderly" category from the Pécs sTBID, while 42 and 12 patients were enrolled to these respective groups in the nationwide survey (Table 1).

In concordance with previously described findings, an overwhelming majority of these injuries were caused by falls. Both databases reflected the relatively high Hungarian in-hospital mortality of sTBI (44.26 % vs 47.94 %). The mortality was about 20 % higher for the elderly and more than 30 % higher in case of the "super" elderly group, with a constantly but only slightly lower mortality rate detected at all groups in the database deriving from the clinical center.

While these mortality figures do not seem to be devastating, it is of note that long-term follow-up of Hungarian sTBI cases indicate an unexpectedly high incidence of late postinjury mortality, most probably associated with the lack of appropriate step-down units and dedicated neurorehabilitation facilities.

Univariate logistic regression analysis of the Pécs sTBID revealed that in-hospital mortality in concordance with data from the IMPACT (International Mission for Prognosis and Analysis of Clinical Trials in TBI) collaboration were significantly associated with first available blood glucose level (Table 2) [48]. Although the effect of coagulopathy/altered hemostasis was close to significant, this factor in light of other factors defining outcome did not appear that important in this age group as it was supposed.

As far as monitoring and treatment is considered, it is of note that ICP over 20 mmHg and cerebral perfusion pressure (CPP) under 60 mmHg proved to be associated with outcome. The finding that ICP monitoring via ventriculostomy catheter ("drain") had a protective effect on in-hospital mortality is also associated with intent-to-treat issues reflecting the willingness to heal potential survivors according to scientific evidence-based guidelines. This is also reflected in the fact that 41 of the 70 elderly (58 %) and 8 of the "super" elderly patients (35 %) received a ventricular catheter for ICP monitoring.

Intriguingly, the length of stay at the ICU as well as occurrence of septic complication or a meningitis/ventriculitis (due to prolonged application of a ventricular catheter) was associated with lower in-hospital mortality, only revealing the fact that those who lived up to the stage when they got severe infectious complications were already through their critical neuro-ICU phase and had a better chance to recover or at least leave the hospital alive.

While significant attempts were made to disseminate evidence-based guidelines for the treatment of the head injured in Hungary in the early 2000s, the actual care of TBI did not change substantially. Although intensive

Table 1 Comparison of demographic data derived from the Pécs Severe Traumatic Brain Injury Database and the nationwide survey of TBI in Hungary [40]

		"Pecs Severe TBI Database"		Hungarian nationwide survey [40]	
Data collection		July 2002–Dec. 2008		Oct. 1, 2002–Dec. 31, 2002	
Total number of cases		305		267	
Overall in hospital mortality		***44.26 %***		***47.94 %***	
Age group		65–80	80+	65–80	80+
Number of cases		70	23	42	12
Gender	Male	50 (71.43 %)	12 (52.17 %)	29 (69.05 %)	7 (58.33 %)
	Female	20 (28.57 %)	11 (47.83 %)	13 (30.95 %)	5 (41.67 %)
Mechanism of injury (%)	**Fall, *n (%)***	**49 (70.00 %)**	**22 (95.65 %)**	**27 (64.29 %)**	**9 (75.00 %)**
	Road traffic accident	9 (12.86 %)	0 (0.00 %)	9 (21.43 %)	2 (16.67 %)
	Other	12 (17.14 %)	1 (4.35 %)	6 (14.29 %)	1 (8.33 %)
In hospital mortality, n (%)		***46 (65.71 %)***	***18 (78.26 %)***	***31 (73.81 %)***	***10 (83.33 %)***

Table 2 Univariate logistic regression analysis of the Pécs Severe Traumatic Brain Injury Database focusing on elderly/super elderly patients

	OR	*P*	95 % CI
On-admission parameters			
Sex	1.47	0.430	0.56–3.85
Age	1.04	0.224	0.97–1.12
Elderly/super elderly	1.88	0.264	0.62–5.68
GCS on admission	0.87	0.055	0.75–1.00
Reaction of pupils	0.35	0.052	0.12–1.01
Mech.: fall/other	1.47	0.462	0.53–4.05
1st glucose level	1.22	0.030	1.02–1.46
Coagulopathy	2.37	0.072	0.92–6.10
Treatment/monitoring parameters			
Drain	0.37	0.037	0.15–0.94
ICP>20	1.04	0.048	1.00–1.08
MABP<90	1.00	0.820	0.99–1.02
CPP<60	1.05	0.023	1.01–1.10
Days in ICU	0.94	0.040	0.89–1.00
Sepsis or CSF inf.	0.19	0.026	0.04–0.82

OR odds ratio; *GCS* Glasgow Coma Scale; *Mech* mechanism; *ICP* intracranial pressure; *MABP* mean arterial blood pressure; *CPP* cerebral perfusion pressure; *ICU* intensive care unit; *CSF* cerebrospinal fluid; *inf* infection

Parameters significantly associated with in-hospital mortality are indicated with bold/italics

care specialists in the late 1990s have already published their national guidelines [40], in 2002 only every fifth sTBI patient received an ICP monitor and less than 50 % has undergone invasive monitoring of their blood pressure [39].

Preliminary data indicate that the care for the head injured have not improved in the past few years either: analysis of 7000 patient records collected in 10 years, provided by the National Insurance Service, indicate that every second Hungarian TBI patient operated for TBI of various severity died within 6 months.

Not surprisingly, the trend that has been observed in detailed analysis of the IMPACT and CRASH (Clinical Randomisation of an Antifibrinolytic in Significant Hemorrhage) data, that predictive models may overestimate the real outcome of sTBI in "low income" (LI) countries, is also demonstrated in Hungary, although it should be considered a "high/middle income" country [49••, 50].

On the basis of these epidemiological studies in Eastern Europe, a clear gap can be identified between the economic background and the quality of TBI care provided by the health care system. Unfortunately, this is particularly true for the geriatric population, where outcome results appear particularly disappointing. The striking controversy between educating, training our physicians to provide state-of-the-art care without making available the necessary resources, and a properly organized structure of health care raises various concerns not only about the actual care but also the future of healing in this region.

While the system is not changed substantially, care for gTBI will be either negativistic with saving resources for younger individuals (under-triage, withheld of care) or will be focused on state-of-the-art, expensive but short acute care, with discharging our gTBI patients to institutions where there is a high chance for their secondary, subacute mortality without a hope to get appropriate neurorehabilitation. Both approaches lead to devastation and burnout of medical personnel either with observing the gTBI cases passing away with minimal care or recognizing the vanity of contemporary ICU strategies in lack of state-of-the-art rehabilitation.

A new European Union–funded nationwide project that is underway to establish step-down units to provide neurorehabilitation in the subacute phase postinjury may represent the light at the end of the rather dark tunnel of TBI care for the region.

Conclusions

The geriatric population is growing; thereby, gTBI is more frequent. These cases frequently harbor a difficult medical history and represent a challenge for care providers.

Results diverge, yet every attempt should be made to achieve similar outcome results as it is feasible in the younger population. This is not a cost-efficient yet rather demanding task particularly in Eastern Europe, where operations and efficacy of the health care system does not keep pace with the development of the economy. Distribution of scientific evidence-based guidelines and treatment protocols as well as enforcement of guideline compliance may make a difference in the care of the gTBI population worldwide, particularly in this region.

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References

Papers of particular interest, published recently, have been highlighted as:
- • Of importance
- •• Of major importance

1. Langlois JA, Rutland-Brown W, Wald MM. The epidemiology and impact of traumatic brain injury: a brief overview. J Head Trauma Rehabil. 2006;21(5):375–8.
2. Murray CJ, Lopez AD. Global mortality, disability, and the contribution of risk factors: Global Burden of Disease Study. Lancet. 1997;349(9063):1436–42.
3. •• Labib N, Nouh T, Winocour S, Deckelbaum D, Banici L, et al. Severely injured geriatric population: morbidity, mortality, and risk factors. J Trauma. 2011;71(6):1908–14. *This paper provides an analysis of 276 patient records from the trauma registry of a Canadian level I trauma center analyzing risk factors and predictors of outcome in the elderly.*
4. Ferrell RB, Tanev KS. Traumatic brain injury in older adults. Curr Psychiatry Rep. 2002;4(5):354–62.
5. Thompson HJ, McCormick WC, Kagan SH. Traumatic brain injury in older adults: epidemiology, outcomes, and future implications. J Am Geriatr Soc. 2006;54(10):1590–5.
6. Lavoie A, Ratte S, Clas D, Demers J, Moore L, et al. Preinjury warfarin use among elderly patients with closed head injuries in a trauma center. J Trauma. 2004;56(4):802–7.
7. Rapoport MJ, Feinstein A. Outcome following traumatic brain injury in the elderly: a critical review. Brain Inj. 2000;14(8):749–61.
8. Goleburn G, Golden C. Traumatic brain injury outcome in older adults: a critical review of the literature. J Clin Geropsychol. 2001;7:161–87.
9. •• Stocchetti N, Paterno R, Citerio G, Beretta L, Colombo A. Traumatic brain injury in an aging population. J Neurotrauma. In press. 2012. *This work collected patient records from three Italian centers including 1366 cases and stratified the data into seven age categories. Every 5th case was over 70 years; thereby, solid conclusions have been drawn via descriptive, univariate, and logistic regression analysis about the importance of age as a predictive factor as well as other players that could influence treatment efficacy and outcome.*
10. •• Lau D, El-Sayed AM, Ziewacz JE, Jayachandran P, Huq FS, et al. Postoperative outcomes following closed head injury and craniotomy for evacuation of hematoma in patients older than 80 years. J Neurosurg. 2012;116(1):234–45. *This paper compares the outcome of patients who have undergone craniotomy for evacuation of traumatically evoked intracranial hematomas over 80 years and 80 years or younger. The results indicate that, although with higher sacrifice in terms of complications and expenses, good outcome is also achievable and desirable in the patient population over age 80 years.*
11. Susman M, DiRusso SM, Sullivan T, Risucci D, Nealon P, et al. Traumatic brain injury in the elderly: increased mortality and worse functional outcome at discharge despite lower injury severity. J Trauma. 2002;53(2):219–23.
12. Vollmer DG, Eisenberg HM. Head injury (including subdural hematoma). In: Hazzard WR, Andres R, Bierman EL, Blass JP, editors. Principles of geriatric medicine and gerontology. 2nd ed. New York: McGraw-Hill; 1990. p. 990–8.
13. Lonner JH, Koval KJ. Polytrauma in the elderly. Clin Orthop Relat Res. 1995;318:136–43.
14. • Woolcott JC, Richardson KJ, Wiens MO, Patel B, Marin J, et al. Meta-analysis of the impact of 9 medication classes on falls in elderly persons. Arch Intern Med. 2009;169(21):1952–60. *This work emphasizes the role of preexisting medications in the etiology of injuries, primarily falls in the elderly. "Polypharmacia" is a significant issue in the elderly and physicians should be aware of its potential devastating consequences*.
15. Hukkelhoven CW, Steyerberg EW, Rampen AJ, Farace E, Habbema JD, et al. Patient age and outcome following severe traumatic brain injury: an analysis of 5600 patients. J Neurosurg. 2003;99(4):666–73.
16. Timiras P. Physiological basis of aging and geriatrics. The nervous system: structural and biochemical changes. CRC Press; 2003.
17. Mina AA, Bair HA, Howells GA, Bendick PJ. Complications of preinjury warfarin use in the trauma patient. J Trauma. 2003;54(5):842–7.
18. Karni A, Holtzman R, Bass T, Zorman G, Carter L, et al. Traumatic head injury in the anticoagulated elderly patient: a lethal combination. Am Surg. 2001;67(11):1098–100.
19. Touger M, Gennis P, Nathanson N, Lowery DW, Pollack Jr CV, et al. Validity of a decision rule to reduce cervical spine radiography in elderly patients with blunt trauma. Ann Emerg Med. 2002;40(3):287–93.
20. Lomoschitz FM, Blackmore CC, Mirza SK, Mann FA. Cervical spine injuries in patients 65 years old and older: epidemiologic analysis regarding the effects of age and injury mechanism on distribution, type, and stability of injuries. AJR Am J Roentgenol. 2002;178(3):573–7.
21. Mack LR, Chan SB, Silva JC, Hogan TM. The use of head computed tomography in elderly patients sustaining minor head trauma. J Emerg Med. 2003;24(2):157–62.
22. Af Geijerstam JL, Britton M, Marke LA. Mild head injury: observation or computed tomography?Economic aspects by literature review and decision analysis. Emerg Med J. 2004;21(1):54–8.
23. Stein SC, Burnett MG, Glick HA. Indications for CT scanning in mild traumatic brain injury: a cost-effectiveness study. J Trauma. 2006;61(3):558–66.
24. Morris Jr JA, MacKenzie EJ, Damiano AM, Bass SM. Mortality in trauma patients: the interaction between host factors and severity. J Trauma. 1990;30(12):1476–82.
25. Taylor MD, Tracy JK, Meyer W, Pasquale M, Napolitano LM. Trauma in the elderly: intensive care unit resource use and outcome. J Trauma. 2002;53(3):407–14.
26. Plaisier BR, Blostein PA, Hurt KJ, Malangoni MA. Withholding/withdrawal of life support in trauma patients: is there an age bias? Am Surg. 2002;68(2):159–62.
27. Jacobs DG. Special considerations in geriatric injury. Curr Opin Crit Care. 2003;9(6):535–9.
28. Jacobs DG, Plaisier BR, Barie PS, Hammond JS, Holevar MR, et al. Practice management guidelines for geriatric trauma: the EAST Practice Management Guidelines Work Group. J Trauma. 2003;54(2):391–416.
29. Meldon SW, Reilly M, Drew BL, Mancuso C, Fallon Jr W. Trauma in the very elderly: a community-based study of outcomes at trauma and nontrauma centers. J Trauma. 2002;52(1):79–84.
30. Mushkudiani NA, Engel DC, Steyerberg EW, Butcher I, Lu J, et al. Prognostic value of demographic characteristics in traumatic brain injury: results from the IMPACT study. J Neurotrauma. 2007;24(2):259–69.
31. Bouras T, Stranjalis G, Korfias S, Andrianakis I, Pitaridis M, et al. Head injury mortality in a geriatric population: differentiating an "edge" age group with better potential for benefit than older poor-prognosis patients. J Neurotrauma. 2007;24(8):1355–61.
32. •• Utomo WK, Gabbe BJ, Simpson PM, Cameron PA. Predictors of in-hospital mortality and 6-month functional outcomes in older adults after moderate to severe traumatic brain injury. Injury. 2009;40(9):973–7. *This work analyzes an Australian state trauma registry, data deriving from more than 400 elderly patients who had suffered moderate or severe TBI in 2 years. Besides*

descriptive data, independent predictors of in-hospital mortality are also identified.

33. LeBlanc J, de Guise E, Gosselin N, Feyz M. Comparison of functional outcome following acute care in young, middle-aged and elderly patients with traumatic brain injury. Brain Inj. 2006;20 (8):779–90.
34. •• Brazinova A, Mauritz W, Leitgeb J, Wilbacher I, Majdan M, et al. 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. 2010;27(9):1549–55. *The authors explore what chances do extremely severe (GCS 3–4) geriatric TBI cases have for survival. The paper enlists predictors of outcome in this subgroup of gTBI cases*.
35. Knudson MM, Lieberman J, Morris Jr JA, Cushing BM, Stubbs HA. Mortality factors in geriatric blunt trauma patients. Arch Surg. 1994;129(4):448–53.
36. Pieracci FM, Eachempati SR, Shou J, Hydo LJ, Barie PS. Degree of anticoagulation, but not warfarin use itself, predicts adverse outcomes after traumatic brain injury in elderly trauma patients. J Trauma. 2007;63(3):525–30.
37. • Brown AJ, Witham MD, George J. Development of a risk score to guide brain imaging in older patients admitted with falls and confusion. Br J Radiol. 2011;84(1004):756–7. *This work focuses on red flags in the diagnosis of traumatic brain injury in the elderly, providing an aid for the triage of such cases*.
38. Sandor J, Szucs M, Kiss I, Ember I, Csepregi G, et al. Risk factors for fatal outcome in subdural hemorrhage. Ideggyogy Sz. 2003;56 (11–12):386–95.
39. Csepregi G, Buki A, Futo J, Sandor J, Gobl G, et al. Management of patients with severe head injury in Hungary, in 2002. Orv Hetil. 2007;148(17):771–7.
40. Csepregi G, Vimlati L, Futo J. Súlyos koponya-agysérültek ellátása Magyarországon 1997-ben: egy országos felmérés eredményei. Orv Hetil. 2000;141:560–7.
41. Hansagi E, Czeiter E, Szabo J, Demeter B, Sandor J, et al. Outcome prediction in case of severe traumatic brain injury: application of the IMPACT outcome calculator for a Hungarian cohort. Abstract. Idegyogy Sz. 63 ed. 2010. p. 214.
42. Mauritz W, Wilbacher I, Majdan M, Leitgeb J, Janciak I, et al. Epidemiology, treatment and outcome of patients after severe traumatic brain injury in European regions with different economic status. Eur J Public Health. 2008;18(6):575–80.
43. Keris V, Lavendelis E, Macane I. Association between implementation of clinical practice guidelines and outcome for traumatic brain injury. World J Surg. 2007;31(6):1352–5.
44. Vukic M, Negovetic L, Kovac D, Ghajar J, Glavic Z, et al. The effect of implementation of guidelines for the management of severe head injury on patient treatment and outcome. Acta Neurochir (Wien). 1999;141(11):1203–8.
45. • Ptyushkin P, Vidmar G, Burger H, Marincek C. Use of the International Classification of Functioning, Disability and Health (ICF) in patients with traumatic brain injury. Brain Inj. 2010;24 (13–14):1519–27. *From the data reported in this manuscript, one can estimate the burden of TBI in Slovenia*.
46. Hukkelhoven CW, Steyerberg EW, Farace E, Habbema JD, Marshall LF, et al. Regional differences in patient characteristics, case management, and outcomes in traumatic brain injury: experience from the tirilazad trials. J Neurosurg. 2002;97 (3):549–57.
47. • Lingsma HF, Roozenbeek B, Li B, Lu J, Weir J, et al. Large between-center differences in outcome after moderate and severe traumatic brain injury in the international mission on prognosis and clinical trial design in traumatic brain injury (IMPACT) study. Neurosurgery. 2011;68(3):601–7. *This paper provides high-quality evidence on the heterogeneity of TBI care in those countries enrolling patients into the trials analyzed*.
48. Murray GD, Butcher I, McHugh GS, Lu J, Mushkudiani NA, et al. Multivariable prognostic analysis in traumatic brain injury: results from the IMPACT study. J Neurotrauma. 2007;24(2):329–37.
49. •• Roozenbeek B, Chiu YL, Lingsma HF, Gerber LM, Steyerberg EW, et al. Predicting 14-day mortality after severe traumatic brain injury: application of the IMPACT models in the Brain Trauma Foundation TBI-trac((R)) New York State Database. J Neurotrauma. In press 2012. *This work joins a chain of studies on the IMPACT database that had led to the construction of a strong predictive model. The study published here is an example of the validation and actual application of the model on a different, IMPACT-independent database and a good resource of predictive factors determining outcome in TBI.*
50. Steyerberg EW, Mushkudiani N, Perel P, Butcher I, Lu J, et al. Predicting outcome after traumatic brain injury: development and international validation of prognostic scores based on admission characteristics. PLoS Med. 2008;5(8):e165.