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Outcome predictors of Glasgow Outcome Scale score in patients with severe traumatic brain injury

Ağır travmatik beyin hasarlı hastalarda Glasgow Sonuç Skalası skoru sonuç belirteçleri

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BACKGROUND
Traumatic brain injury is a major public health problem due to high mortality and morbidity among survivors.

METHODS
We performed a retrospective cohort study of patients with severe traumatic brain injury. We recorded the attending physician's evaluation of the patient's consciousness, the patient's demographics, routine physical measurements, and medical interventions. We used Glasgow Coma Scale and Extended Glasgow Outcome Scale.

RESULTS
We included 60 patients (83.3% males, mean age: 49.5 years). The Glasgow Coma Scale score was 4.8±1.9 and the Extended Glasgow Outcome Scale score was 2.9±2.5 points. Linear regression for higher Extended Glasgow Outcome Scale score explained 59.8% of the variance and revealed the duration of hospital stay and the presence of epidural hematoma as significant predictors. The classification tree for the higher Extended Glasgow Outcome Scale score revealed the following variables to be important: the duration of hospital stay, Glasgow Coma Scale score, partial pressure of carbon dioxide, surgery, response time of out-of-hospital emergency team, systolic and diastolic blood pressure, fall, and basis fracture.

CONCLUSION
Standardized inpatient protocol on monitoring, intervention and outcome recording should be adopted to make future comparisons more useful and to promote benchmarking between trauma centers in order to improve care for patients with severe traumatic brain injury.

Key Words: Traumatic brain injury/outcome/predictors.

AMAÇ
Travmatik beyin hasarı, sağ kalan kişilerde yüksek mortalite ve morbiditeye neden olan majör bir kamu sağlığı problemidir.

GEREÇ VE YÖNTEM
Ağır travmatik beyin hasarına sahip olan hastalara ilişkin retrospektif bir kohort çalışması gerçekleştirdik. Tedavi eden doktorun hastanın bilincine ilişkin değerlendirmesi, hastanın demografik özellikleri, rutin fiziksel ölçümleri ve tıbbi girişimler kaydedildi. Glasgow Koma Skalası ve genişletilmiş Glasgow Sonuç Skalası kullanıldı.

BULGULAR
Bu çalışmaya 60 hasta (%83,3 erkek, ortalama yaş 49,5 yıl) dahil edildi. Glasgow Koma Skalası skoru 4,8±1,9 ve genişletilmiş Glasgow Sonuç Skalası skoru 2,9±2,5 puan idi. Daha yüksek genişletilmiş Glasgow Sonuç Skalası skoruna yönelik lineer regresyon, varyansın %59,8'ini açıkladı ve önemli prediktörler olarak epidural hematomanın varlığını gösterdi. Daha yüksek genişletilmiş Glasgow Sonuç Skalası skoruna yönelik sınıflama ağacı, şu değişkenlerin önemli olabileceğini gösterdi: Hastanede kalma süresi, Glasgow Koma Skalası skoru, parsiyel karbondioksit basıncı, cerrahi, hastane dışı acil ekibinin yanıt zamanı, sistolik ve diyastolik kan basıncı, düşme ve kafa kaidesi kırığı.

SONUÇ
Ağır travmatik beyin hasarlı hastalara yönelik bakımı geliştirmek için travma merkezleri arasında gelecekte daha yararlı karşılaştırmalar yapmak ve karşılaştırmalı değerlendirmeyi ilerletmek üzere; izleme, girişim ve sonuç kaydı ile ilgili standardize yatılı tedavi protokolü benimsenmelidir.

Anahtar Sözcükler: Travmatik beyin hasarı/sonuç/prediktörler.

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Traumatic brain injury (TBI) remains a major public health problem due to the high mortality and the long-term morbidity and disability among survivors. The incidence of severe TBI ranges (depending somewhat also on the study design) from 9 to 17 per 100,000 inhabitants.[1-3] According to the severity of head trauma, patients can be grouped into mild TBI (in 30-91%), moderate TBI (in 4-30%) and severe TBI (in 5-40%) groups.[2,4-6]

Traumatic brain injury (TBI) patients are prevailingly male (58-74%).[1-3] However, females were 1.8 times more likely to die of their brain injury and 1.6 times more likely to experience poorer outcomes (that is, severe disability or persistent vegetative state) than males.[7] On the contrary, a study from Australia showed that women with severe TBI, after matching for initial injury severity and age at injury, demonstrated a better early outcome as indicated by their Glasgow Outcome Scale (GOS) scores than men (OR 4.2 points) and had a shorter duration of hospital stay (OR 9.0 days).[8,9]

Age is an exceedingly important parameter affecting recovery from TBI. The mean age of TBI victims varies from 32 to 49 years.[1,3,9] Older patients, after isolated TBI, have poorer functional status at discharge and make less improvement at one year compared to all other patients. These worse outcomes occur despite less severe TBI in elderly patients as measured by a higher Glasgow Coma Scale (GCS) score upon admission.[10] Patients between 18 and 29 years of age had the lowest mean score on GOS, which correlated with the low admission GCS score because of polytrauma associated with severe TBI.[10] Ethnic minorities had significantly worse long-term functional outcomes after TBI, which was related to a lack of health insurance.[11] Better outcomes of patients after TBI is ensured by early intubation[12,13] and surgery.[1,14]

Recovery of neurological patients is usually long, and TBI patients can gradually improve even after several months.[15] Early intensive rehabilitation may improve the functional outcome of patients with TBI in the early months after injury and hence increase the chance of their returning to work early.[16,17] Only 4.9% of patients hospitalized due to TBI had hospital neurorehabilitation, 68% within one month after injury. Patients were classified as: 10.9% severe, 23.4% moderate and 65.7% mild TBI, and 5% were younger than 16 years and 25% older than 65 years. (2) Extended Glasgow Outcome Scale (GOSE) proved to be a useful tool for measuring disability even 10 years after TBI and was also proven to correlate well with other measures of human functioning.[18]

Table 1. Extended Glasgow Outcome Scale (GOSE)*

Score outcome	Category
1	Dead
2	Vegetative state
3	Lower severe disability
4	Upper severe disability
5	Lower moderate disability
6	Upper moderate disability
7	Lower good recovery
8	Upper good recovery

* Patient's overall rating is based on lowest outcome category indicated on the scale.

In Slovenia, there are more than 300 deaths due to TBI (among 2 million population) per year, and out-of-hospital emergency services in the country have a trained doctor on the staff at all times to provide recommended procedures in TBI patients, and there are reports on the beneficial outcomes when applied.[12,13] We thus wanted to test which factors predict outcomes in severe TBI patients.

MATERIALS AND METHODS

We performed a retrospective cohort study of severe TBI patients injured in Celje district who were admitted to the hospital from January 1, 2004 to December 31, 2008. Patients who were recognized as dead in the field were excluded due to lack of reliable data about the cause of death. The emergency medical service (EMS) of Celje covers a population of 125,000 inhabitants. On average, 4.6 emergency interventions are performed per day. We extracted data from routine EMS reports, which are routinely filled in by the attending physician. The physician's evaluation of the patient's consciousness, the patient's demographics, routine physical measurements, and medical interventions were recorded. An experienced attending physician assessed the patient's health status. Early outcome of patients was assessed by GCS. Only TBI patients with a GCS<9 as assessed i the field were included. Appropriate intervention according to the emergency care protocol was administered in each case and the interventions recorded.

We used GOSE (Table 1), which is a global assessment of independent living and social reintegration that is widely used as an outcome measure in brain injury research, to analyze long-term functional outcome. The assessment was carried out using the structured interview for the GOSE, with questions covering the following areas: 1) consciousness; 2) independence inside and outside the home; 3) resumption of normal social roles (work, social and leisure activities, personal relationships); and 4) residual symptoms interfering with daily life. The GOSE does not require a detailed psychological or neurologic examination and can be administered by professionals from different backgrounds. The GOS consists of five catego-

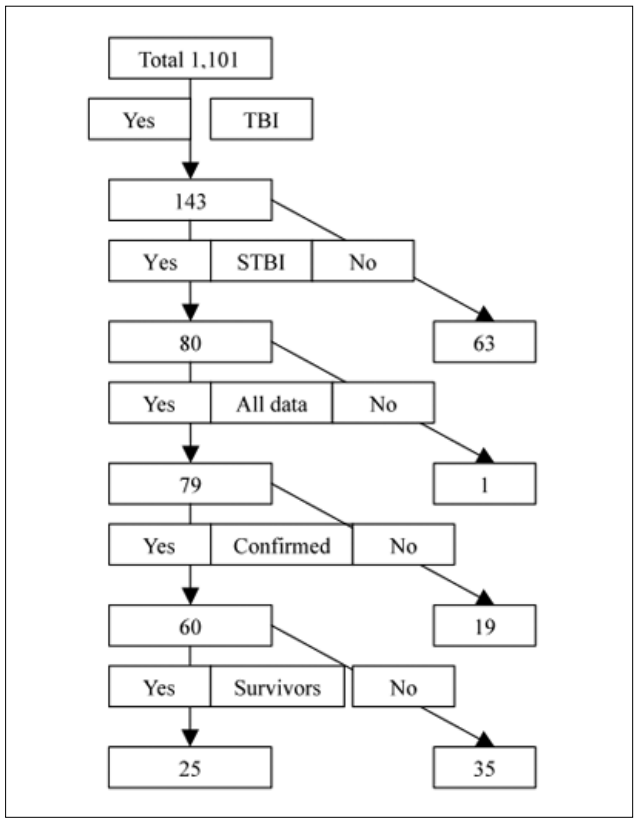

Fig. 1. Flow chart of TBI patients. [Figure legend: TBI: Traumatic brain injury; STBI: Severe traumatic brain injury; Confirmed: STBI confirmed in hospital by imaging and exclusion of intoxication or other causes for GCS<9 at trauma site.]

ries: dead, vegetative state, severe disability (conscious, but disabled), moderate disability (disabled, but independent), and good recovery. For the GOSE, the latter three categories are divided into upper and lower bands. The scales include the outcome categories "dead" and "vegetative state," but only the categories of conscious survival were applicable in the current study. For the purposes of analysis, any patients disabled before the injury were treated as severely disabled and not separately identified.[19] The GOSE score of each survivor was obtained using a structured telephone interview by the severe TBI patient's family physician using a standardized data form containing nine yes/no questions, which proved to be reliable for GOS assessment in neurologically injured patients.[20]

We reviewed the patients' out-of-hospital protocols of EMS intervention and hospital charts for surgery performed, length of hospital stay, discharge, rehabilitation, and other outcomes.

The data were analyzed using the Statistical Package for the Social Sciences (SPSS) 13.0 statistical package (SPSS Inc., Chicago, IL, USA). We calculated the descriptive statistics. Spearman's correlation coefficient (r) was used to analyze the association between the different variables. We used independent samples t-test. Values of $p<0.05$ were considered to be statistically significant. Multiple logistic regression and classification tree analysis were performed to identify predictive factors of different outcomes after TBI.

Table 2. The demographic and clinical characteristics of the patients in the sample

Characteristic	Number	%
Sex		
Male	50	83.3
Female	10	16.7
Causes for severe TBI		
Fall	16	26.7
Traffic accident	39	65.0
Gunshot	4	6.7
Consequence of severe TBI		
Cerebral edema	36	60.0
Subdural hematoma	15	25.0
Subarachnoidal bleeding	29	48.3
Skull fracture	31	51.7
Basis fracture	7	11.7
Contusion of the brain	40	66.7
Epidural hematoma	4	6.7
Intracerebral bleeding	10	16.7
Hematocephalus	7	11.7
Pneumocephalus	4	6.7
Skin injury	11	18.3
Surgery	24	40.0
Presence of alcohol in the blood	8	13.3
Intubation	51	85.0
Resuscitation	3	5.0
Polytrauma	25	41.7
Hospital rehabilitation	17	28.3
Epileptic seizures during hospital stay	10	16.7
Drugs during resuscitation or hospital stay		
Analgesic	24	40.0
Anesthetic, sedative	45	75.0
Liquids	52	86.7
Antiemetic	2	3.3
Relaxant	25	41.7
Hospital pneumonia	26	43.3

TBI: Traumatic brain injury.

RESULTS

In the observed period, EMS took care of 1,101 patients: 143 (13.0%) of them for TBI and 60 (5.5%) for severe TBI (Fig. 1).

Among 60 patients, 50 (83.3%) were males (Table 2). The average age of the patients was 49.5±20.8 years. The average response time of the out-of-hospital emergency team was 10.3±5.4 minutes. The GCS score was 4.8±1.9 and the GOSE score was 2.9±2.5 points. The average saturation of blood with oxygen was 85.0±12.5, the average pCO_2 in the arterial blood was 35.5±13.0 kPa, and the average systolic and diastolic blood pressures were 118.5±37.5 mmHg and

Table 3. Linear regression analysis for the higher GOSE score

Dependent variable	Independent variable	B	Lower 95% C.I. for B	Higher 95% C.I. for B	p
GOSE score	Age (years)	-0.009	-0.034	0.016	0.501
	GCS score	0.336	0.000	0.672	0.050
	Duration of hospital stay (days)	0.029	0.007	0.052	0.013
	Brain contusion	1.099	-0.135	2.333	0.079
	Epidural hematoma	2.761	0.493	5.030	0.018
	Intracerebral bleeding	-0.592	-2.157	0.974	0.450
	Gunshot	-0.277	-2.376	1.822	0.791
	Surgery	0.866	-0.277	2.009	0.134
	Resuscitation	-1.237	-3.498	1.023	0.276
	Anesthetic, sedative	0.474	-0.940	1.889	0.502
	Antiemetic	-0.488	-4.516	3.540	0.808
	Hospital pneumonia	0.451	-0.791	1.693	0.468

GOSE: Extended Glasgow Outcome Scale; GCS: Glasgow Coma Scale; CI: Confidence interval.

75.0±23.0 mmHg, respectively. The duration of hospital stay was 19.8±27.2 days.

The GOSE score was negatively correlated with the age of the patients (r=-0.259, p=0.048) and positively correlated with GCS score (r=0.290, p=0.024) and with the duration of hospital stay (r=0.475, p<0.001). Patients with brain contusion had higher GOSE score in comparison to others (3.3±2.7 vs. 2.1±1.6, p=0.033). Patients with epidural hematoma had higher GOSE score in comparison to others (6.8±1.5 vs. 2.6±2.3, p=0.001). Patients with intracerebral bleeding had lower GOSE score in comparison to others (1.7±1.6 vs. 3.1±2.5, p=0.039). Patients who were injured by a gunshot had lower GOSE score than others (1.0±0 vs. 3.0±2.5, p<0.001). Patients that underwent surgery had higher GOSE score than others (3.8±2.6 vs. 2.7±2.2, p=0.015). In patients in whom resuscitation was needed, the GOSE score was lower than in other patients (1.0±0 vs. 3.0±2.5, p<0.001). Patients that received anesthetics or sedatives had higher GOSE scores than others (3.3±2.6 vs. 1.7±1.5, p=0.005). Patients that received antiemetics had lower GOSE scores than others (1.0±0 vs. 2.9±2.5, p<0.001). Patients with nosocomial pneumonia had higher GOSE scores than others (4.2±2.4 vs. 1.9±2.0, p<0.001). Linear regression for higher GOSE score explained 59.8% of the variance and revealed the duration of hospital stay and the presence of epidural hematoma as significant predictors (Table 3).

The classification tree for higher GOSE score revealed the following variables to be important in explaining a better GOSE: longer hospital stay, higher initial GCS score, higher pCO_2, surgery, shorter response time of the out-of-hospital emergency team, low systolic and diastolic blood pressure, patient fall as cause of TBI, and cranial basis fracture (Fig. 2).

DISCUSSION

The independent predictors for higher GOSE score were higher GCS score at the site of the injury, longer stay in the hospital and the presence of epidural hematoma. Similarly, the classification tree proved results of linear regression statistics that the duration of hospital stay was most important in predicting the outcome after severe TBI. Namely, patients that stayed in the hospital more than 12 days scored on average 3.5 more points on the GOSE scale as compared to those with a shorter stay (Node 2: 4.9±2.1 vs. Node 1: 1.4±1.5). This may indicate that many patients die during the first days after severe TBI, which might be due to the severity of the TBI itself or due to concomitant polytrauma or hospital complications. We can support this assumption also by our finding that in all patients with a shorter hospital stay (except in 2), the GOSE score was 1 (they died during the hospital stay or in the first 6 months after severe TBI). As is evident from the left branch of the classification tree, the second and third most important factors for better GOSE outcome were higher on-site GSC and the presence of surgery, which might have played a key role in a satisfying outcome for these two survivors. The favorable effect of surgery was also demonstrated in other studies.[14]

If we follow the right branch of the classification tree, we can see that the second most important factor for better outcome after severe TBI was pCO_2; a level higher than 34 mmHg improved the GOSE score by two points (Node 5: 3.2±2.1 vs. Node 6: 5.2±1.9). This is not unexpected because higher pCO2 is an indicator of a better cardiac output and hence better brain blood circulation.[21] In those with adequate circulation (systolic blood pressure over 95 mmHg), GOSE improved by three points (Node 11: 2.7±1.5 vs. Node 12: 5.7±1.7), showing that patients with hypovolemia or other causes of low systolic systemic blood pressure have worse outcomes, which was also shown in other studies.[15,17] On the other hand, lower values of diastolic blood pressure (below 65 mmHg) improved

GOSE by more than two points (Node 14: 5.1±1.5 vs. Node 13: 7.2±0.8), probably indicating that this might improve brain circulation in anticipated raised intracranial pressure. In the next step, we found the best outcome in those patients with severe TBI without skull fracture (7.5 points), followed by patients who suffe-

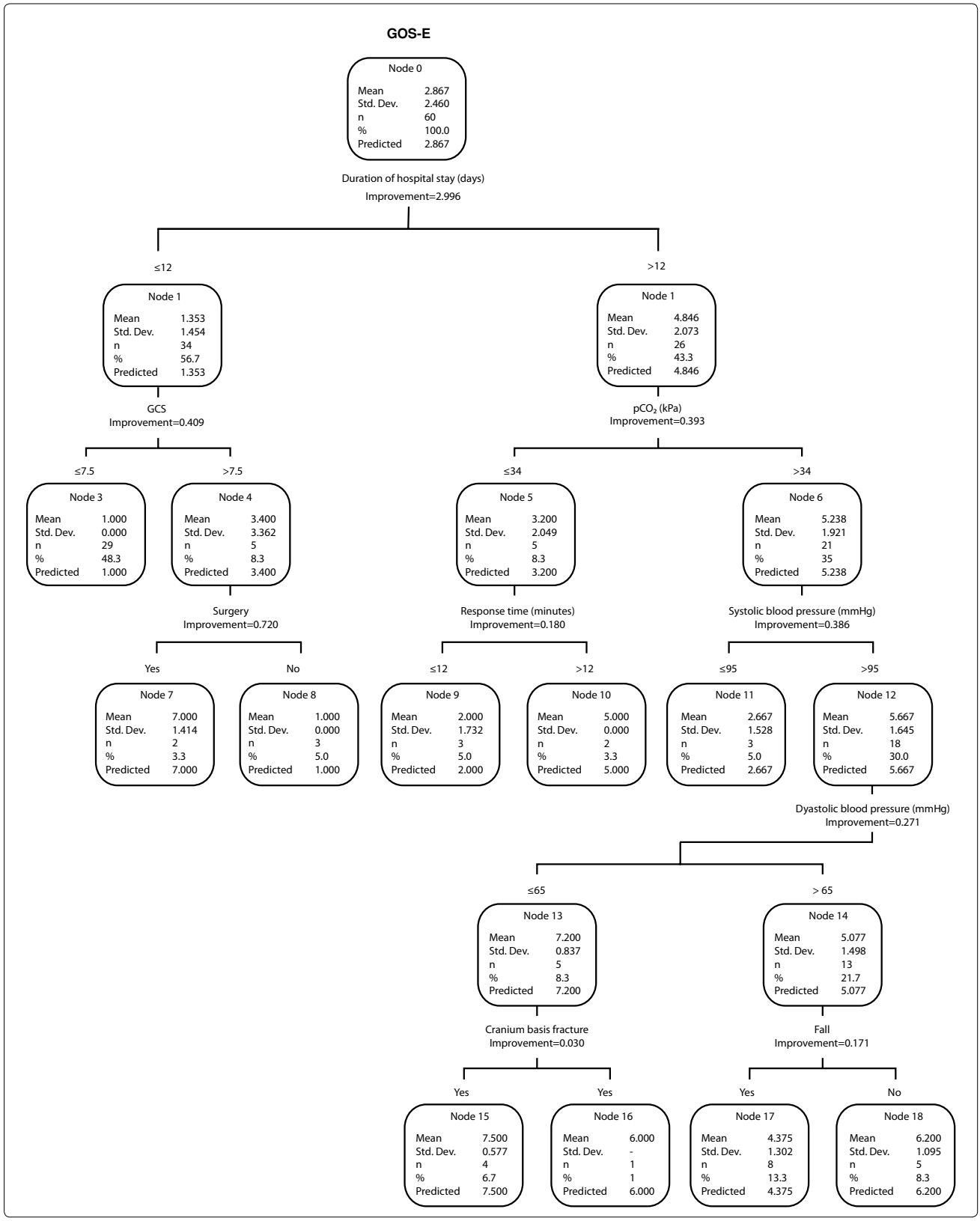

Fig. 2. The classification tree for higher GOSE score. [GOSE: Extended Glasgow Outcome Scale; GCS: Glasgow Coma Scale.]

red severe TBI after a fall (6.2 points), patients with skull fracture (6.0 points), and those with causes of severe TBI other than fall (4.0 points).

The mean age of the patients in our sample at the time of injury was 49.5 years, older than in a recent Swedish and Australian study (31.2 years and 31.4 years, respectively).[9,18] In the majority of the cases, the injury was caused by traffic accidents (65%). As reported in a Swiss study,[3] none of our gunshot victims (6.7%) survived. The length of hospital stay in our study (20 days) is consistent with the findings of other researchers.[3] Post-traumatic epilepsy is one of the most important complications after TBI,[22] and our finding that 16.7% of patients suffered from post-traumatic epilepsy is consistent with the findings of Andelic and co-workers.[9,18]

The overall in-hospital mortality was 58%, which is consistent with the findings of Elm and co-workers (52% mortality rate).[3] The average GOSE score after severe TBI in our sample was 2.9±2.5 points. The majority of patients (70%) had a bad outcome and 30% made good recovery, which is consistent with the findings of Hawley and co-workers,[23] who at follow-up found 26% of patients with severe disability, 44% with moderate disability and 30% with good recovery.

The strengths of our study were the inclusion of all eligible patients, which minimizes the risk for selection bias, the use of standardized scales in assessing patients, and the fact that patients on the field were assessed by an experienced and well-trained attending EMS physician. The main limitation is the relatively small sample. Another limitation is also the retrospective design of the study. Further studies should have a prospective design and should aim at a larger sample.

In conclusion, adequate out-of-hospital and in-hospital treatments proved to play a role in better outcomes as measured in GOSE scores. A decision tree provides a good insight into the hierarchy of measures that improve long-term outcomes after severe TBI. It could present the basis for the development of a standardized inpatient protocol on monitoring, intervention and outcome recordings. Such a protocol would make future comparisons more useful and also promote benchmarking between the trauma centers in order to improve care for severe TBI patients.

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