

# Does Emergency Severity Index Predict Acuity Among Traumatic Brain Injury Patients?

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## Abstract

**Aim:** It is unclear whether emergency severity index (ESI) is valid to triage patients with trauma. We aimed to determine the accuracy of ESI in both prehospital and hospital settings.

**Materials and Methods:** This study was an observational prospective cohort where in patients with traumatic brain injury (TBI) were followed from the accident scene to the hospital. Used resources and timing indices were collected both on the scene as well as at the hospital. A logistic regression was performed to ascertain the effects of clinical parameters on the likelihood of survival of patients with TBI regarding 24 hour mortality.

**Results:** A total of 185 patients were included in this study. The mortality rate was 14% (25/185). The logistic regression model was statistically significant at  $\chi^2=57.8$ ,  $p=0.001$ . An enter logistic regression analysis showed that used resources either in prehospital or in hospital significantly improved predictions related to mortality. The model explained the 49% variance in survival of patients with TBI.

**Conclusion:** The ESI-used resources can be used to triage patients with TBI for pre-hospital and hospital emergency care. It is recommended that ESI triage tool be used to triage patients with TBI.

**Keywords:** Traumatic brain injury, emergency severity index, triage, prehospital emergency

## Introduction

Trauma is the main cause of morbidity and mortality in people aged <40 years, and is the third most common cause of death worldwide. It is responsible for 5 million deaths annually (1-3). Time is considered an essential determinant for the outcome of patients with trauma (4). A fundamental tenet of trauma care is the "golden hour." It is the immediate time after injury when resuscitation, stabilization, and rapid transport are perceived to be most beneficial for the patient (5, 6). The basic principle of caring for patients with trauma is to provide timely care. Prehospital prompt response, resuscitation,

immobilization, and rapid transfer of patient to trauma centers are very important factors in the trauma management system (7, 8). It has been shown that providing definitive care earlier at trauma centers decreases mortality (9, 10). Although prompt response is common in developed countries, it is unclear whether response time is plausible in developing countries, and what its effects on mortality are (11). Any delay in management of progressive hemorrhagic injury is a significant cause of morbidity and mortality in the emergency department (ED). A computed tomography (CT) scan reliably predicts progressive hemorrhagic injury in patients with trauma; therefore, time to CT scan (12) as well as other tests such as hematocrit (HCT), which is a significant independent predictor of mortality in patients

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with trauma (13-15), must be monitored rigorously. Therefore, it can be concluded that timing indices have a great impact on management of patients with trauma. Literature shows that little empirical knowledge exists about the exact influence of prehospital time, hospital time, radiological and laboratory testing time, and time to therapeutic interventions on outcome of patient with trauma. In addition, because traumatic injuries are increasingly recognized as a leading source of morbidity and mortality in developing countries, context-specific research is necessary to identify opportunities for the prevention and improved treatment.

Triage systems are also important tools for reducing time to definite care (16, 17). Although emergency severity index (ESI) is practiced worldwide, little data exist about its use in trauma centers. ESI uses patient acuity (stability of vital signs and degree of distress) as well as expected used resource to assign five triage levels from level 1 (most urgent) to level 5 (least urgent) (18). As compared to other triage systems, estimating expected resource in the triage assignment is a unique feature of ESI. The nurses in ED need to clearly understand that the estimate of resources is related to the standards of care. Resources can be diagnostic services such as tests, procedures, consults, or therapeutic interventions. However, validity and reliability of ESI have been well documented in the literature. It is unclear whether used resource rating system of ESI predicts acuity in patients with trauma. Therefore, we aimed to determine the description of the timing and preventive care measures in prehospital and hospital settings with the mortality of the patients with trauma and validity of used resource rating system of ESI among patients with traumatic brain injury (TBI).

## Materials and Methods

This study was an observational prospective cohort that followed patients with TBI from the accident scene to the hospital between February and September 2016.

Data collection was performed after receiving approval from the ethics committee at Mashhad University School of Medicine (No. 940948). The study is granted exemption from ethics committee, so informed consent is not required because the study involves no more than minimal risk to the subjects.

### Setting

This study was conducted in the Hasheminezhad Hospital in Mashhad, Razavi Khorasan, Iran, which is the second largest Level 1 trauma center (320 beds) in the city. The hospital provides several specialties, including neurosurgical, emergency medicine, orthopedic, surgical, and internal medicine services, 24 hours per day. Annually, the hospital ED receives 14,500 patients with trauma, most of whom arrive by ambulance. All nurses in the ED have both a Bachelor of Science (B.S.) in nursing and Trauma Certified Registered Nurse certification. All emergency physicians in the ED are specialists in emergency medicine. Emergency medical services (EMS) are provided by professional individuals who are trained to provide basic trauma life support, such as immobilization, airway management, and intravenous fluid therapy, during ambulance transfers. All paramedics must have a B.S. in EMS. They transfer patients with trauma from the scene to the EDs in the shortest possible time with the aim of reducing morbidity as well as mortality.

### Data collection

The patients with TBI who were received by ambulance and admitted to the ED were assessed. Patient records were used to collect relevant data, including age, gender, mechanism of injury, and medical history. Prehospital transfer time and hospital timing measures and used resources were recorded.

Prehospital transfer time included time taken to reach scene and transfer time from scene to hospital. Hospital time included time taken to emergency physician visit and neurosurgeon specialist visit, as well as time taken to perform imaging studies (X-ray, CT scan, and sonography), laboratory examination (hemoglobin, HCT), and intubation. Used resources in prehospital and hospital settings were calculated based on ESI method and conventional method. For example; if a patient receives a chest X-ray and a sonography in ED, she/he would receive score 1 in ESI method and score 2 in conventional method. All imaging studies are considered score 1 in ESI method apart from the numbers of resources. In other hand, each imaging study scores 1 in conventional method and 2 in the above example. In fact, each intervention was scored one in conventional method.

To assess in-hospital mortality, we examined death rates in the first 24 hours post-injury. All included patients were followed up for mortality over 24 hours in ED. Therefore, based on their outcome (dead or alive) in the first 24 hours post-injury, patients with TBI were divided into two groups.

### Patient selection

During the study period, patients with TBI who met the following criteria were included in the study: the mechanism of injury (MOI) was a traffic accident, they were transported directly from the scene by an EMS ambulance, they had an injury severity score (ISS>9), they were aged more than 18 years but less than 85 years, and they had at least one vital sign parameter higher than zero at the scene (to include only cases without clinical death). Exclusion criteria included incomplete data in either the pre-hospital or hospital patient records (i.e., vital signs and parameters), pregnancy, comorbidities (diabetes, cardiovascular disease, and chronic obstructive pulmonary disease), and transfer time from the scene to the hospital of more than 60 min and transfer of patients to other health-care centers in the first 24 hours.

**Variables:** Used resources and time periods were assessed in prehospital and hospital settings.

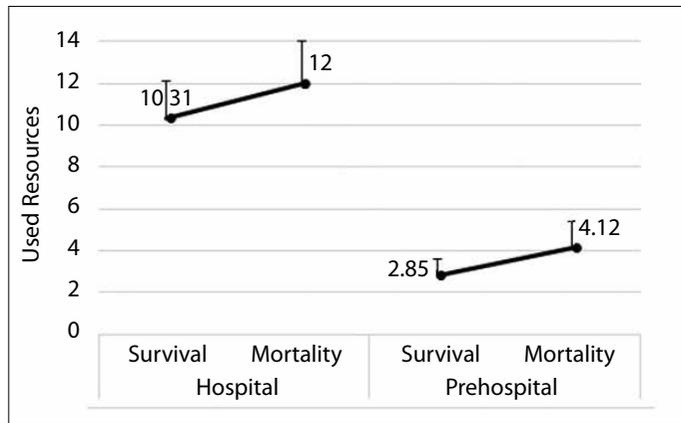
### Used resources based on emergency severity index (ESI Ver.4)

ESI is a five-level triage algorithm that categorizes patients by evaluating both patient acuity and resource needs. To sort patients into one of the five triage levels, the ESI algorithm uses four decision points (A, B, C, and D). At decision point C, the nurse assigns ESI levels 3-5 by assessing both acuity and predicted resource needs. Acuity level is assessed by the triage nurse. If a patient does not meet high acuity level criteria (ESI level 1 or 2), the triage nurse evaluating expected resources needs to help determine a triage level (ESI level 3, 4, or 5). Resources can be hospital services, tests, procedures, consults, or interventions in ESI (18, 19). The nurse then predicts the number of resources a patient will need to reach a disposition. It is important to note that resource prediction is only used for less acute patients (level 3, 4, or 5). ESI levels 3, 4, and 5 are differentiated by the nurse's de-

termination of how many different resources are needed to make a patient disposition (20). On the basis of the triage nurse's predictions, patients who are expected to consume no resources are classified as ESI level 5, those who are likely to require one resource as ESI level 4, and those who are expected to need two or more resources as ESI level 3. Patients who need two or more resources have been shown to have higher rates of hospital admission and mortality, and longer lengths of stay in the ED (21).

**Used resources based on the conventional method**

Used resources were also calculated based on the conventional method. Each intervention was valued one in the conventional method. For example, simple dressing or splint scored one. In the conventional method, patient with two graphies receives two scores, whereas they receive one score based on the ESI method. All used resources were summed up for each patient.



**Figure 1.** Frequency of used resources in pre-hospital and hospital settings based on the emergency severity index method

**Table 1.** Characteristics of patients in both groups

Characteristics	All (n=185)	Survival (n=160)	Mortality (n=25)	Characteristics	All (n=185)	Survival (n=160)	Mortality (n=25)
Age years old (mean+SD)	39.01±18.4	38.1±17.7	44.2±21.9	Gender female (n, %)	44 (24)	37 (23.1)	7 (28)
Blunt trauma (n, %)	170 (92)	147 (91.9)	23 (92.0)	Penetrating trauma (n, %)	15 (8)	13 (8.1)	2 (8.0)
<b>Prehospital</b>							
Time to scene (min) (mean+SD)	15.17±6.05	15.20±6.09	15.03±5.45	Scene to hospital time (min) (mean+SD)	15.42±6.15	15.42±6.21	15.37±5.45
Transfer time (min) (mean+SD)	47.5±76.3	49.8±81.7	33.3±13.3	Used resources	3.02±0.93	2.85±0.74	4.12±1.26
<b>Hospital</b>							
Time to physician visit (min) (mean+SD)	15.47±6.17	15.48±6.23	15.40±5.48	Time to specialist visit (min) (mean+SD)	15.51±6.58 n=155	15.51±7.05	15.50±6.24
Time to graphy (min) (mean+SD)	15.35±6.51 n=170	15.24±6.54 n=152	17.07±6.22 n=18	Time to CT scan (min) (mean+SD)	15.47±6.48 n=173	15.36±6.50 n=156	17.17±6.26 n=17
Time to sonography (min) (mean+SD)	13.15±7.35 n=62	12.47±7.36 n=56	17.36±6.23 n=6	Time to laboratory exam (min) (mean+SD)	15.21± 7.24 n=175	15.17±7.26 n=156	15.59±7.14 n=19
Hemoglobin (mg/dL) (mean+SD)	13.98±2.70 n=135	14.20±227 n=118	12.46±4.56 n=17	Hematocrit (%) (mean+SD)	40.62±6.54 n=136	41.33±4.99 n=118	36.00±11.92 n=18
Used resources	10.54±1.91	10.31±1.79	12.0±2.04				

\*Significant data is marked

**Prehospital time**

Transfer time is composed of "Time to Scene" and "Scene to Hospital time." Time to scene is defined as the time required for EMS to deploy after emergency call; and scene to hospital time is defined as the time from departing scene to arrival at the hospital.

**Hospital time**

Time to hospital resources including emergency physician, specialist, intubation, imaging studies (X-ray, sonography, and CT scan), laboratory exam [hemoglobin (mg/dL) and HCT (%)] were computed from call to EMS as well as during in-hospital stay. Time period was calculated in minutes.

**Confounders analysis**

We considered several potential confounders of the association between acuity of head injury and mortality during the first day of admission. These included MOI, ISS<9, and other life-threatening injuries. For analysis, traffic accident survivors (driver, passenger, motorcycle, bicycle, and pedestrian) were included in the study. Other MOIs were excluded because they may have coincided with different patterns of injury. Patients with TBI with a minimum ISS score of 9 were included only if that score belonged to a brain injury. TBI is often associated with a high-velocity circumstance; hence, injuries to other parts of the body are common.

**Statistical analysis**

Timing measure variables that were normally distributed between the two independent groups were compared using the T-test. Acuity scales for survival probability in patients with TBI, such as the ESI, were calculated based on both prehospital and hospital parameters.

The effect of each predictor on the outcome variable was assessed individually by performing a univariate analysis. Variables showing a statistically significant association at 5% level of significance in the univariate analysis were included in the multivariate analysis. Multivariate logistic regression was used to develop a prognostic model for the outcome (mortality, no/yes) of the first 24 hour of admission. Models using a pre-defined group of predictor variables (method, "enter") in the univariate analysis as well as multivariate analysis were employed.

**Table 2.** Univariate analysis of variables in the equation according to the enter method (Ref=Survival)

Variable	Odds ratio	95% CI		p
		Lower	Upper	
<b>ESI method</b>				
Used resources in prehospital	0.261	0.152	0.448	0.000
Used resources in hospital	0.591	0.453	0.772	0.000
Total used resources (Prehospital plus hospital)	0.649	0.547	0.771	0.000
<b>Conventional method</b>				
Used resources in prehospital	0.507	0.377	0.683	0.000
Used resources in paraclinic	2.756	1.677	4.527	0.000
Used resources in hospital	0.428	0.289	0.634	0.000
Used resources in paraclinic and hospital	0.778	0.579	1.045	0.096
Total used resources	0.682	0.566	0.822	0.000

In prognostic research, the logistic regression model is a commonly used statistical method. It is estimated when the outcome variable follows a binomial distribution by using maximum likelihood methods. Coefficients of the final model are presented together with the respective odds ratio (OR) and a corresponding 95% confidence interval (CI).

Statistical analyses were performed with IBM Statistical Package for the Social Sciences version 18.0 software (IBM SPSS Corp.; Armonk, NY, USA). Data are presented as a mean (standard deviation) for continuous variables and as proportions for categorical variables.

## Results

### Patient characteristics

Clinical characteristics of the 185 patients are demonstrated in Table 1. The mean age of the patients was 39 years, and 76% were men. Overall, 116 (71%) patients were pedestrians or motorcycle riders, and 170 (92%) had a blunt injury. The mean transfer time was 39 min. The survival rate was 86% (25/185). In either the prehospital or hospital setting, patients in the mortality group were not significantly older ( $p>0.05$ ). The proportions of both groups also did not differ with respect to gender. The frequency of used resources in prehospital and hospital settings based on ESI method is illustrated in Figure 1.

### Survival analysis

Univariate logistic regression analysis showed that used resources (calculated either by ESI or by the conventional method) is inversely associated with survival, which means that severely injured patients

**Table 3.** Multivariate analysis of variables according to the enter method (Ref=Survival)

Variable	B	S.E.	Wald	df	Sig.	Exp (B)	95% C.I.	
							Lower	Upper
ESI-used resources in hospital	-0.727	0.185	15.45	1	0.000	0.483	0.336	0.694
Para-clinical resources in hospital	1.379	0.443	9.688	1	0.002	3.972	1.667	9.468
ESI-used resources in prehospital	-0.655	0.317	4.259	1	0.039	0.519	0.279	0.968
Constant	8.180	2.201	13.813	1	0.000	3570.004		

**Table 4.** Comparison of time measures between survival and mortality groups (min)

Characteristics (minutes)	All	Survival	Mortality	p
Time to physician visit* mean+/-SD	58.15±77.2 (n= 185)	61.2±82.4 (n=160)	38.4±15.7 (n=25)	0.171
Time to intubation mean+/-SD	93.97±107.1 (n=60)	107.6± 122.9 (n=38)	70.3±68.5 (n=22)	0.196
Time to graphy mean+/-SD	102.05±83.03 (n=170)	102.5±87.2 (n=152)	97.7± 29.1 (n=18)	0.816
Time to laboratory exam mean+/-SD	150.0±117.5 (n=175)	155.1±122.1 (n=156)	107.8±53.5 (n=19)	0.098
Time to sonography	63.9±45.1 (n=60)	65.4± 46.9 (n=54)	50.5± 21.3 (n=6)	0.446
Time to CT scan	96.5±83.6 (n=173)	97.1± 87.7 (n=156)	90.8± 25.5 (n=17)	0.769

\*Prehospital transfer time is included.

consumed more resources than other patients with TBI (Table 2). A multivariate logistic regression was performed to ascertain the effects of clinical parameters on the likelihood of survival of patients with TBI. The analysis showed that used resource is calculated based on ESI method either in prehospital or in hospital settings, and paraclinical resource predicts survival significantly. The model provided a statistically significant improvement over the constant-only model. The logistic regression model was statistically significant at ( $\chi^2$  (2, n=185) =57.894, p=0.0001). The model explained the 86.5% variance in survival of patients with TBI. Nagelkerke  $R^2$  (49%) indicated a moderate relationship between prediction and grouping. The correct prediction rate was 91.4% (98.1% for survival and 48.0% for mortality). An enter logistic regression analysis showed that ESI-used resources in prehospital and hospital settings both inversely improved predictions (p<0.05) (Table 3). Higher use of resources in prehospital and hospital settings predict a decrease in the probability of survival. In contrast, paraclinical resource consumption positively associated with survival. Alive patients often stay longer in ED than dead ones did; therefore, the probability of being tested increased. Survival group did not differ from mortality group in terms of time measures (Table 4).

## Discussion

The result of this study showed that used resources based on the ESI method in patients with head trauma are valid, which means that prioritizing used resources based on the ESI method may have a significant association with mortality of patients with head trauma. ESI scale prediction is valid both in prehospital and hospital settings. It is also worth noting that this method provides a stronger validity than the conventional method (that takes a value of one for each resource) does. The more used resources increased, the less patients survived, as an increase in the used resources was associated with 48% decrease in survival probability in prehospital and 52% decrease in survival probability in the emergency room setting. This is because critically ill patients used more resources and had a higher mortality risk.

Used resources were calculated using two methods: conventional and ESI. In the conventional method, each used resource is assigned one value, whereas in the ESI scale, some of measures taken for the patients with trauma such as immobility or laboratory tests and radiographies are calculated once, no matter how many they are. Moreover, as some measures taken for patients with trauma such as immobility or several radiographies, CT scans, and sonographies are more frequent among patients with trauma, validity of the ESI scale in predicting the used resources could be significantly important with regard to the fact that no study has been conducted in this regard. Although in the regression model of the conventional method (whether in the prehospital or hospital settings), the relationship of the used resources with mortality was significant; in the multiple regression model, it was not significant and variables were not included in the final model. Of course, the only resources used in the paraclinical resources including laboratory tests and radiographies were significant because patients who survived could undergo more diagnostic tests in the emergency room. As a result, this variable was included in the final model. Therefore, receiving more diagnostic tests was associated with four times higher chance of survival comparing to those not receiving diagnostic tests. The underlying cause may be that a simple radiography or a blood test can be requested for patients with trauma even if they are not critically ill. This

leads less critically ill patients to consume more resources. In contrast, radiography and tests may not be a priority for critically ill patients, and therefore, paraclinical resources did not increase for them. Elshove et al. (22) showed that performing a simple radiography is the most commonly used resource in category 4 and 5 patients.

We observed in the univariate regression model that a rise in used resources (except for laboratory tests), whether calculated using the conventional or the ESI method, indicated severity of the patient's illness and increased risk of mortality. ESI-used resources (ESI method) was significant in the multiple regression model. This means that the ESI method is valid to calculate resources in patients with trauma. Compared to clinical measures, radiographies and laboratory tests as resource have limited power to differ between critically ill patients and outpatients; therefore, counting several radiographies of the patients as one radiography or several laboratory tests as one test is enough to make a difference between critically ill patients and outpatients. However, clinical measures such as intravenous line, monitoring and other significantly increased scores, whereas patients with less severe illness receive fewer clinical measures. Table 3 suggests that patients who received more resources in prehospital setting or in the emergency room had decreased survival chances by 48% and 52%, respectively. These findings are in line with the findings of other studies (23). Grossmann et al. (24) showed that mean resources used by patients with more severe illnesses (level 1) was significantly more than those used by patients with less severity (Level 1: 4.68, level 2: 3.17, level 3: 2.68, level 4: 1.08 and level 5: 0.32). Mortality in level 1 patients was equal to 27.3. In another study, the mean of used resources used by level 1 patients was 7.48 (25). Mortality in level 1 patients was 58.6%. As these studies suggest, the more frequent critically ill patients were, the more resources were also used. Although these two studies were conducted in general hospitals, the results of these studies indicated that this scale is also valid in patients with trauma. The mean of resources used by the mortality group in prehospital settings and the emergency room was 4.12 and 12, respectively, which was significantly more than the mean in the survival group (2.85 and 10.31). Bigger number of resources used for critically ill patients compared to previous studies may be because patients with trauma need more intervention. Previous studies revealed that 85% of level 2 patients use more than two resources (22).

## Study limitations

Our study was limited to one hospital trauma center in a densely populated area of a metropolitan city. We could not extend the study period further because strict supervision was required to collect reliable data. Therefore, other studies may want to replicate this study with larger sample sizes. Other limitation of this study was the fact that the paramedics collected data in the field, and we used the documented data in the ED. Paramedics were well trained and educated, so documented data can be considered reliable.

## Conclusion

The ESI triage system is valid to calculate used resources among patients with trauma. ESI has greater power to predict mortality based on used resources than the conventional method because radiographies and laboratory tests are calculated once. Therefore, the ESI-used resource protocol may be used to predict mortality in patients with trauma.

**Ethics Committee Approval:** Ethics committee approval was received for this study from the Ethics Committee of Mashhad University of Medical Sciences (Approval Number: 940948).

**Informed Consent:** The study is granted exemption from ethics committee, so informed consent is not required because the study involves no more than minimal risk to the subjects.

**Peer-review:** Externally peer-reviewed.

**Author Contributions:** Concept - A.M.; Design - Z.N., H.Z., A.M.; Supervision - Z.N., H.Z., A.M.; Resources - A.M., M.E., A.A.; Data Collection and/or Processing - Z.N., H.Z., A.M.; Analysis and/or Interpretation - Z.N., H.Z., A.A., M.E. and A.M.; Literature Search - Z.N., H.Z., A.M.; Writing Manuscript - Z.N., H.Z., A.M.; Critical Review - Z.N., H.Z., A.A., M.E. and A.M. Other - M.E., A.A.

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