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Original Article

Validation of guidelines for field triage of injured patients for major trauma in patients of brain and spinal injury

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Abstract The field triage guidelines have been widely implemented in the Korean trauma system. This study aimed to evaluate and validate whether it is reliable to use the field triage guidelines for predicting severe traumatic brain injury (TBI) and traumatic spinal injury (TSI) patients. This study retrospectively analyzed in-hospital cohort registries of all TBI and TSI patients, who visited the emergency department (ED) of the Jeju National University Hospital from 1 January 2013 to 31 December 2015. The primary outcome was defined as TBI and TSI patients with an injury severity score (ISS) > 15. Secondary outcomes were defined as cases in which one or more of the following conditions: in-hospital death, ISS > 15, admission to the intensive care unit, emergency surgery. We enrolled 14,889 TBI and TSI patients who visited ED, of which 7,966 (53.5%) were triage positive. The overall sensitivity, specificity and area under the curve (AUC) of the full cumulative field triage guidelines step's model (Step 1 + 3 + 4 criteria) for primary outcome were 82.8%, 47.0%, and 0.646, respectively. In the results for secondary outcomes, the specificity did not show a significant difference, but the sensitivity decreased to 66.5% and AUC to 0.568. The results of this study suggest that further optimization of the field triage guidelines is needed to identify high-risk TBI and TSI patients.

Key words: Triage, Traumatic brain injury, Spinal injuries, Criteria

INTRODUCTION

Traumatic brain injury (TBI) and traumatic spinal injury (TSI) are among the most common causes of trauma related death and long term disability. These are not only serious health problems, but also increases the socioeconomic burden of increasing medical costs, reducing work capacity and productivity. In order to reduce death and disability associated with TBI and TSI, the regional trauma system must be well organized and operated.[1,2] The goal of the field triage process is to ensure that trauma patients are transported to a trauma center or hospital that is best equipped to manage their specific injuries, in an appropriate and timely manner, as the circumstances of injury might warrant. The field triage process for trauma patients is one of the most important factors for effective operation of the regional trauma system.[3]

The guidelines for field triage of injured patients (field triage guidelines) proposed by the United States Center for Disease Control and Prevention (CDC) is widely used as a standard for triage protocols for trauma patients at the scene. In Korea, emergency medical services (EMS) rescuers use the same standards.[3,4] Recently in Korea, regional trauma centers have begun to operate in earnest, thereby the appropriate triage at the scene is emphasized for effective operation of the regional trauma system.[5,6] Until now, there have been few studies to validate the application of the field triage guidelines at the scene to

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identify the severe TBI and TSI in Korea. The purpose of this study is to evaluate and validate whether it is reliable to use the field triage guidelines for predicting severe TBI and TSI patients.

METHODS

Study design

This study retrospectively analyzed in-hospital cohort registries of all injured patients, who visited the emergency department (ED) of the Jeju National University Hospital over the period of three years (from 1 January 2013 to 31 December 2015). During the study period, our hospital served at the highest level of trauma center in the regional trauma system.

Data collection

This study used data from electronic medical records (EMRs) of the Jeju National University Hospital and the Emergency Department-based Injury In-depth Surveillance (EDIIS). Appropriate triage of trauma patients is one of the most important factors for prognosis of trauma patients not only in the field, but also in the initial process of ED. Therefore, since 2011 in our ED, the field triage guidelines have been used as a triage tool for trauma patients to quickly identify major trauma patients and to provide timely and appropriate treatment for major trauma patients. An initial triage of trauma patients was performed and recorded in EMRs by emergency medical technicians (EMTs), who had the same education level and qualify as EMS rescuers in Korea. The field triage guidelines data included the status (positive or negative) of twenty-two criteria at each four decision step. The EDIIS, managed by the Korea Centers for Disease Control and Prevention (KCDC), is a collection of data for all trauma patients who visit EDs that participate in a surveillance system. This registry contains a variety of data on trauma patients, including demographics, injury-related characteristics, computer-based time stamps, injury severity score (ISS), and outcomes of patients. We linked and analyzed EMRs data and EDIIS data using a deterministic linking methodology based on two common identifiers (hospital registration number and ED visit time).

Study participants

The eligible participants were selected from all trauma patients who visited our ED from 1 January 2013 to 31 December 2015. Among the eligible participants, patients diagnosed with TBI or TSI in the ED were included in this study. Non-TBI or TSI patient and incompatible data were excluded. TBI was defined as the following diagnosis in the International Classification of Disease, 10th Edition (ICD-10): S01.0～S01.9, S02.0～S02.1, S02.3, S02.7～02.9, S04.0, S06.0～S06.9, S07.0～07.1, S07.8～S07.9, S09.7～S09.9, T01.0～T02.0, T04.0, T06.0. Also, TSI was defined as the following diagnosis of ICD-10: S12.0～12.2, S12.7～12.9, S13.0～S13.6, S14.0～S14.1, S22.0～S22.1, S23.0～23.3, S24.0～S24.2, S32.0, S33.0, S33.1, S33.5, S34.0～S34.3.

There were 26,857 eligible participants during the study, of which 11,968 were excluded. A total of 14,889 participants was analyzed and divided into two groups, "Triage positive" and "Triage negative", based on their meeting the field triage guidelines. Also, the "Triage positive" group was categorized into three different subgroups from step 1: physiologic (PHY) criteria, step 3: mechanism of injury (MOI) criteria, step 4: special consideration (SC) criteria, sequentially. However, step 2: Anatomical criteria were excluded from the subdivision, because it contained criteria for injuries of other specific anatomical structures not associated with TBI and TSI (Fig. 1).

Variables and outcome measure

The demographic characteristics of the patients included age, gender, Glasgow Coma Scale (GCS) score and vital sign on arrival at the ED, inter-hospital transfer, revised trauma score (RTS), ISS, EMS usage, operation, and disposition of ED. The injury related characteristics of the patients were activity at the time of injury, location of injury, intentionality, and mechanism of injury. This study was designed to evaluate whether the application of the filed triage guidelines is effective for screening patients with severe TBI or TSI. Therefore, the primary outcome variable was defined as TBI and TSI patients with ISS > 15. Secondary outcome variables were defined as cases in which one or more of the following conditions: in-hospital death, ISS > 15, admission to the intensive care unit (ICU), emergency surgery.

Statistical methods

Continuous variables were presented as a mean ± SD and were compared using t-tests for normal distribution. Categorical variables were presented as proportions and were compared using a Chi-square test or Fisher's exact tests. All statistical analyses were conducted using two-tailed

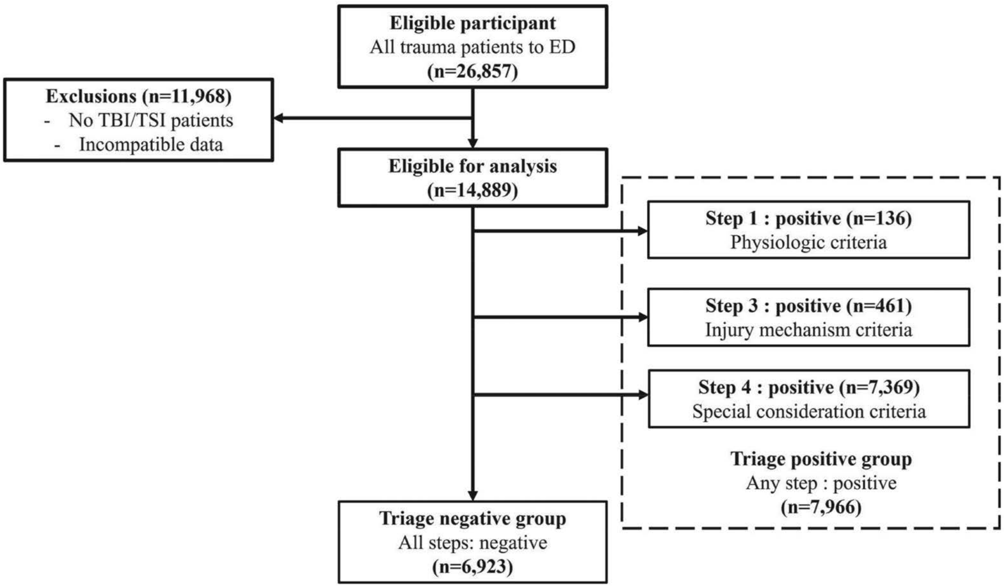

Figure 1. Flowchart of study participants.

tests. Significance levels of $p<0.05$ (two-tailed) were accepted. Sensitivity, specificity, under-triage (1-sensitivity), over-triage (1-specificity), positive predictive value (PPV), negative predictive value (NPV), positive likelihood ratio (LR+), negative likelihood ratio (LR−) and area under the curve (AUC) were calculated to validate the application of the field triage guidelines in ED. Data analyses and management were performed using Stata/SE version 14.0 (Stata Corp., College Station, TX).

Ethical approval

The study was approved by the institutional review board (IRB) of the Jeju National University Hospital (IRB no. 2020-03-003), also approved by KCDC for the use of EDIIS data. The requirement for informed consent was waived by the IRB.

RESULTS

During the three year study period, a total of 14,889 patients with TBI or TSI visited our ED. Among these patients, 7,966 (53.5%) were triage positive; 269 (1.8%) had ISS>15; 710 (4.8%) had one or more of the following conditions: in-hospital death, ISS>15, ICU admission, emergency surgery. The proportion of female patients was lower than that of male patients, regardless of the triage result. There were 2,768 (40.0%) and 3,316 (41.6%) female patients in the triage negative and positive group with a significant difference ($p=0.042$). The mean age of patients in triage positive group was lower than triage negative (29.8±31.0 vs 35.7±11.6, $p<0.001$). However, in the age subgroup analysis, the proportion of patients over 55 years old was significantly higher in the triage positive group (37.4% vs 1.5%, $p<0.001$). Also, the triage positive group had a higher proportion of inter-hospital transfer ($p<0.05$), hospital admission ($p<0.01$), ICU admission ($p<0.01$). There was a statistically significant difference between the two groups of GCS, vital signs, ISS, and RTS, but there was no clinical significance (Table 1). In comparing injury related characteristics, the triage positive group had the highest frequency of injuries during daily activities (51.2%), whereas the triage negative group had the highest frequency of injuries during unpaid work (31.1%). In addition, the triage positive group had the highest frequency of injuries in the home (39.0%), while the triage negative group had the highest frequency of injuries in the traffic road (46.0%). In the mechanism of injury, fall (42.8%) was the highest proportion the triage positive group, but motor vehicle collisions (MVCs) (38.0%) were the highest proportion in the triage negative group (Table 2). The overall sensitivity, specificity and AUC of the full cumulative field triage guidelines step's model (step 1+3+4 criteria) for identifying TBI and TSI patients with ISS>15 were 82.8% and 47.0% and 0.646 respectively, and the overall rate of

Table 1. Demographic characteristics of the "Triage positive" and "Triage negative" groups

	Triage − (N = 6,923)	Triage + (N = 7,966)	Total (N = 14,889)	p-value
Females: n (%)	2,768 (40.0)	3,316 (41.6)	6,084 (40.9)	0.042*
Age (years): mean ± SD	35.7 ± 11.6	29.8 ± 31.0	32.5 ± 24.2	< 0.001†
1 to 17: n (%)	304 (4.4)	4,595 (57.7)	4,899 (32.9)	< 0.001*
18 to 54	6,516 (94.1)	392 (4.9)	6,908 (46.4)	
55 and up	103 (1.5)	2,979 (37.4)	3,082 (20.7)	
GCS score	15.0 ± 0.4	14.9 ± 1.1	14.9 ± 0.8	< 0.001†
SBP (mmHg): mean ± SD	135.6 ± 18.8	135.9 ± 25.9	135.7 ± 22.0	0.578†
DBP (mmHg): mean ± SD	87.4 ± 12.9	83.3 ± 15.6	85.7 ± 14.2	< 0.001†
Pulse rate (per min): mean ± SD	84.2 ± 14.9	99.3 ± 24.5	92.3 ± 21.9	< 0.001†
Respiratory rate (per min): mean ± SD	20.0 ± 1.4	23.7 ± 5.7	22.0 ± 4.6	< 0.001†
Body temperature (°C): mean ± SD	36.5 ± 0.6	36.5 ± 1.7	36.5 ± 1.3	0.002†
Inter-hospital transfer, yes: n (%)	711 (10.3)	899 (11.3)	1,610 (10.9)	0.047*
EMS usage, yes: n (%)	1,883 (27.2)	1,861 (23.4)	3,744 (25.2)	< 0.001*
Pre-hospital CPR: n (%)	7 (0.1)	22 (0.3)	29 (0.2)	0.016‡
RTS: mean ± SD	7.8 ± 0.1	7.8 ± 0.6	7.8 ± 0.4	< 0.001*
ISS: mean ± SD	2.1 ± 2.5	2.5 ± 4.1	2.3 ± 2.3	< 0.001*
Operation: n (%)				0.025*
No operation	6,596 (95.3)	7,661 (96.2)	14,257 (95.7)	
Emergent operation	165 (2.4)	158 (2.0)	323 (2.2)	
Elective operation	162 (2.3)	147 (1.8)	309 (2.1)	
ICU admission, yes: n (%)	62 (0.9)	291 (3.7)	353 (2.4)	< 0.001*
Disposition of ED: n (%)				< 0.001‡
Discharge	5,898 (85.2)	6,563 (82.4)	12,461 (83.7)	
Transfer	66 (0.99)	75 (0.9)	141 (0.9)	
Admission	958 (13.8)	1,303 (16.4)	2,261 (15.2)	
Death	1 (0.01)	25 (0.3)	26 (0.2)	

*Chi-square test, †t-tests, ‡Fisher's exact tests, GCS: glasgow coma scale, SBP/DBP: systolic/diastolic blood pressure, CPR: cardiopulmonary resuscitation, RTS: revised trauma score, ISS: injury severity score

under-triage was 17.8% and the overall rate of over-triage was 53.0% (Table 3). In comparison of receiver operating curves (ROC) for primary outcome by each cumulative step, the AUC was the highest in cumulative step model of the PHY criteria and the MOI criteria (0.737) (Fig. 2). In the diagnostic metrics for secondary outcomes, the overall sensitivity, specificity and AUC of the full cumulative field triage guidelines step's model (step 1 + 3 + 4 criteria) were 66.5%, 47.1% and 0.568 respectively (Table 4). Also, AUC was the highest in PHY and injury mechanism cumulative step model (Fig. 3).

DISCUSSION

This study aimed to validate that the field triage guidelines are suitable as a triage tool for severe TBI and TSI. The field triage process aims to minimize under-triage

Table 2. Injury characteristics of the "Triage positive" and "Triage negative" groups

	Triage − (N = 6,923)	Triage + (N = 7,966)	Total (N = 14,889)	p-value
Activities: n (%)				< 0.001*
Paid work	1,438 (20.8)	709 (8.9)	2,147 (14.4)	
Unpaid work	2,156 (31.1)	1,246 (15.7)	3,402 (22.9)	
Daily activity	1,611 (23.3)	4,081 (51.2)	5,692 (38.2)	
Leisure of play	871 (12.6)	1,253 (15.7)	2,124 (14.3)	
Others	847 (12.2)	677 (8.5)	1,524 (10.2)	
Places: n (%)				< 0.001*
Home	1,194 (17.3)	3,108 (39.0)	4,302 (28.9)	
Indoor building	564 (8.2)	882 (11.1)	1,446 (9.7)	
Traffic road	3,182 (46.0)	2,191 (27.5)	5,373 (36.1)	
Industrial facilities	586 (8.4)	362 (4.5)	948 (6.4)	
Commercial area	734 (10.6)	817 (10.3)	1,551 (10.4)	
Beach/river	565 (8.1)	536 (6.7)	1,101 (7.4)	
Unspecified area	98 (1.4)	70 (0.9)	168 (1.1)	
Intention: n (%)				< 0.001*
Accidental	6,209 (89.7)	7,736 (97.1)	13,945 (93.6)	
Assault	678 (9.8)	210 (2.7)	888 (6.0)	
Self-harm/Suicide	36 (0.5)	20 (0.2)	56 (0.4)	
Injury mechanism: n (%)				< 0.001*
Blunt	1,636 (23.6)	1,658 (20.8)	3,294 (22.1)	
Stabbing	293 (4.2)	273 (3.4)	566 (3.8)	
Fall	1,272 (18.4)	3,408 (42.8)	4,680 (31.4)	
Motor vehicle crash	2,632 (38.0)	1,723 (21.6)	4,355 (29.3)	
Others	1,090 (15.8)	904 (11.4)	1,994 (13.4)	
Alcohol related, yes: n (%)	1,016 (14.7)	325 (4.1)	1,341 (9.0)	< 0.001*

*Chi-square test

Table 3. Validation of the each step of field triage guideline for primary outcome

	N	ISS > 15 (n)	Step	Triage + , n	Sens., %	Spec., %	PPV, %	NPV, %	AUC
Cumulative steps	14,889	269	1	136	28.3	99.6	55.9	98.7	0.639
			1 + 3	597	50.6	96.8	22.8	99.1	0.737
			1 + 3 + 4	7,966	82.2	47.0	2.8	99.3	0.646
Independent steps	14,889	269	1	136	28.3	99.6	55.9	98.7	0.639
			3	527	39.0	97.1	19.9	98.9	0.681
			4	7,673	57.2	48.6	2.0	98.4	0.529

ISS: injury severity score, Sens.: sensitivity, Spec.: specificity, PPV: positive predictive value, NPV: negative predictive value, AUC: area under the curve

so that major trauma patients receive the right care in the right place at the right time. At the same time, over-triage should be minimized as much as possible in order to efficiently use limited medical resources within the regional trauma system. In the present study, the overall sensitivity and specificity of the field triage guidelines step model for identifying TBI and TSI patients with ISS > 15 were 82.8% and 47.0%, respectively, and the overall rate of

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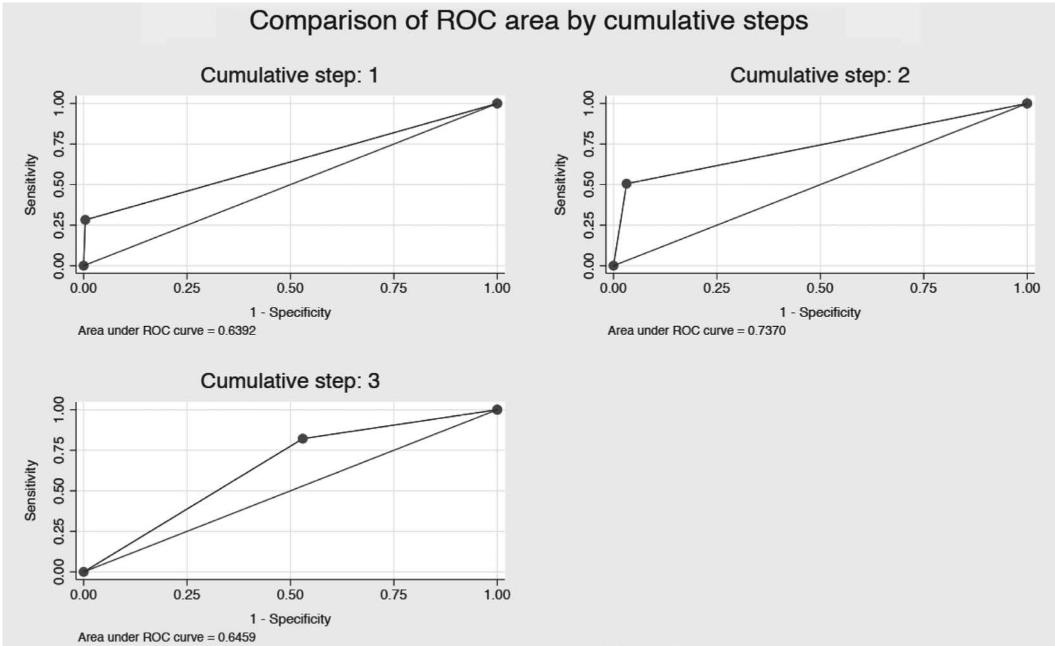

Figure 2. Comparison of receiver operating curves for primary outcome by cumulative steps.

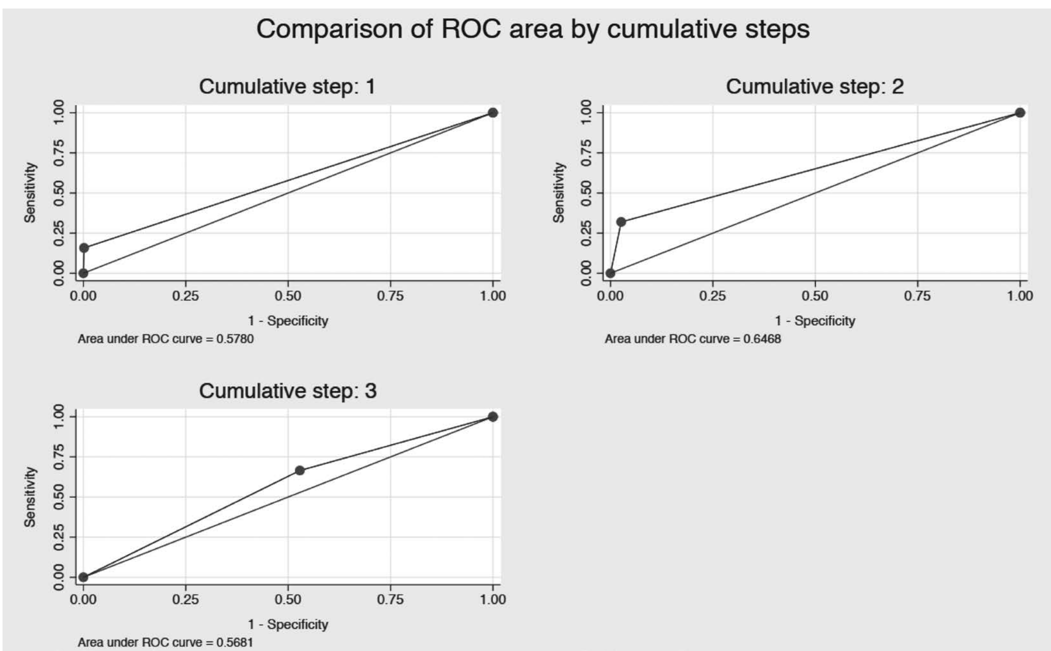

Figure 3. Comparison of receiver operating curves for secondary outcomes by cumulative steps.

under-triage was 17.8% and the overall rate of over-triage was 53.0%. The American College of Traumatology College Trauma Committee proposed an ideal target level of under-triage at 5% in identifying major trauma patients. For this goal, 25% to 35% of over-triage was suggested as acceptable.[7] In a large US study of 122,345 all trauma patients, the overall under-triage rate and over-triage rate of the filed triage guidelines were reported to be 14.2% and 31.3%, respectively.[8] Compared to this, our findings showed that the field triage guidelines are not yet

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Table 4. Validation of the each step of field triage guideline for secondary outcome

	N	2nd outcomes (n)	Step	Triage +, n	Sens., %	Spec., %	PPV, %	NPV, %	AUC
Cumulative steps	14,889	710	1	136	15.8	99.8	82.4	95.9	0.578
			1+3	597	32.0	97.4	38.0	96.6	0.647
			1+3+4	7,966	66.5	47.1	5.9	96.6	0.568
Independent steps	14,889	710	1	136	15.8	99.8	82.4	95.9	0.578
			3	527	24.5	97.5	33.0	96.3	0.610
			4	7,673	50.6	48.4	4.7	95.1	0.495

2nd outcomes: one or more of the following conditions - In-hospital death, ISS > 15, ICU admission, Emergency surgery, Sens.: sensitivity, Spec.: specificity, PPV: positive predictive value, NPV: negative predictive value, AUC: area under the curve

optimized to identify severe TBI and TSI and determine the level of destination hospital. The under-triage rate showed acceptable values in this study, but the over-triage rate was relatively higher in TBI and TSI patients.

In this study, the PHY criteria were highly specific, but insensitive for identifying severe TBI and TSI patients. The PHY criteria are the most important indicators that predict severe TBI and TSI, and the strongest predictors of trauma-related death.[9,10] However, the physiological parameters and signs of neurological abnormalities in patients with TBI and TSI may deteriorate rapidly compared to the initial evaluation. In particular, elderly patients are often accompanied by cognitive and physical disabilities due to preexisting comorbidities, therefore they are at a higher risk of not having a normal physiological response to trauma. Also, compared with younger patients, GCS score in elderly patients tends not to accurately reflect the severity of the injury.[11-14] Furthermore, the initial neurological examination is an important factor in the triage of TBI and TSI, but previous studies have reported that the neurological evaluation of EMS rescuers is less reliable in assessing injury severity.[13-16] These conditions interfere with the accurate judgment of EMS rescuers at the scene and are the leading causes of under-triage in TBI and TSI patients. Therefore, it is important to sequentially evaluate other steps to reduce under-triage.

In previous studies, the MOI criteria and the SC criteria have been reported to effectively reduce the likelihood of under-triage, while modestly increasing in over-triage.[8,14,17-19] The results of this study demonstrate that the cumulative application of the MOI criteria only increased over-triage by 2.8%, but showed an effect of reducing under-triage by 22.3%. This finding suggests that an accurate evaluation of the MOI criteria is a valuable and important process in field triage for severe TBI and TSI patients. Falls and MVCs are the most common mechanisms of injury for severe TBI and TSI. MVCs are the leading causes in the adolescent and young adults, while falls are the leading causes in the elderly and children.[20-23] However, several studies in the United States have reported that TBI and TSI patients with falls tend to be under-triage compared to MVCs patients due to inadequate training and erroneous understanding about the MOI criteria by EMS rescuers. As a result, these patients had a higher rate of transport to non-trauma centers, and a higher rate of transfer to the highest level trauma center.[13,15,23] Also, a study in Korea reported that the current MOI criteria were not fully optimized for practical application at the scene, and this resulted in inappropriate evaluation by EMS rescuers.[6] Given the patterns of under-triage associated with the MOI criteria, the regional trauma system should provide a systematic training program for EMS rescuers and implement the EMS quality assurance process. In addition, further optimization of the MOI criteria is needed to make EMS rescuers easier and more obvious to use. In the process of evaluating SC criteria, EMS rescuers determine the level of destination hospital based on the presence or absence of underlying conditions or comorbidities to help identify patients with serious injuries among those who have not met the other three steps. In this study, the SC criteria showed an effect of reducing the under-triage by 31.6% in TBI and TSI patients, however, it was found that the over-triage increased dramatically by 49.8%. Considering that the proportions of children and the elderly in the triage-positive group were 57.5% and 37.4%, respectively, these findings suggest that the age criterion of the special consideration criteria have a significant impact on the triage results of TBI and TSI patients. It also suggests the need

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to evaluate and improve the feasibility and effectiveness of each criterion of the SC criteria in order to reduce the problem of over-triage.

There are limitations to consider in this study. First, this study was a cross-sectional study in one national university hospital in Jejudo and not a nationwide population based study. So, the results of this study did not reflect the difference in trauma system between domestic regions. Second, in this study, the filed triage guidelines were evaluated in our ED by EMTs. Therefore, other factors that influence decision-making, such as the environmental factors of the scene and the quality level of EMS rescuers, were not considered. In actual field triage of TBI and TSI patients by EMS rescuers, the diagnostic metrics of the field triage guidelines may differ from our study results. Third, the impact of anatomical criteria was not reflected in this study, because it contained criteria for injuries of other specific anatomical structures not associated with TBI and TSI.

CONCLUSION

In this study, the overall sensitivity, specificity of the field triage guidelines for identifying TBI and TSI patients with ISS > 15 were 82.8% and 47.0%. Although, to date, the field triage guidelines are the useful triage tool for TBI and TSI patients, our results suggest that the field triage guidelines are not yet optimized to identify severe TBI and TSI and determine the level of destination hospital. In the future, studies for further optimization are needed for each criterion of the field triage guidelines, and improvements are needed to be effectively applied at the scene.

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PREVIOUS PRESENTATION IN CONFERENCES

This study was presented as a poster at the 2017 autumn scientific meeting of the Korean Society of Emergency Medicines on October 19, 2017 in Incheon, Korea.

CONFLICTS OF INTEREST

No potential conflict of interest relevant to this article was reported.

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None declared.

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