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Validity of Korean Triage and Acuity Scale for Predicting In-Hospital Mortality in Patients with Acute Traumatic Brain Injury : A Nationwide Population-Based Study of 2018-2020

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Objective : This study aimed to evaluate the clinical validity of the Korean triage and acuity scale (KTAS) in predicting in-hospital mortality and surgical intervention in patients with acute traumatic brain injury (TBI).

Methods : We conducted a retrospective cohort study using data from the National Emergency Department Information System (NEDIS) collected between January 2018 and December 2020. Patients aged ≥20 years with acute TBI (International Classification of Diseases, 10th revision [ICD-10] S06.1–S06.9) admitted through the emergency department (ED) within 24 hours of injury were included. Initial KTAS classification and modified KTAS after physician evaluation were analyzed. The primary endpoint was in-hospital mortality, and the secondary endpoint was the need for craniotomy or craniectomy. Predictive performance was assessed using logistic regression and receiver operating characteristic analysis.

Results : A total of 37450 patients were analyzed, with an overall in-hospital mortality of 11.5%. Craniotomy or craniectomy were performed in 9.8% of the TBI patients. Patients classified as initial KTAS level 1 had a 10.33-fold higher risk of in-hospital mortality (95% confidence interval [CI], 5.96–17.88) compared to those in level 5, while modified KTAS level 1 patients showed a 25.96-fold increased risk (95% CI, 6.37–105.76). The area under the curve (AUC) for in-hospital mortality was 0.750 for initial KTAS and 0.751 for modified KTAS, while the AUC for predicting surgical intervention was 0.666 for initial KTAS and 0.669 for modified KTAS. Retriage demonstrated the accuracy of the predictive validity of initial KTAS for in-hospital mortality.

Conclusion : KTAS is an effective tool for early risk stratification in acute TBI, particularly for identifying critically ill patients. Retriage supplements the predictive validity of initial KTAS, supporting its role in guiding clinical decision-making. Further research is warranted to validate KTAS in broader TBI populations and refine its utility for surgical decision-making.

Key Words : Mortality · Treatment outcome · Traumatic brain injury · Triage.

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INTRODUCTION

Emergency departments (EDs) in Korea are currently facing critical issues such as overcrowding, ambulance diversion, and increasing legal burdens on healthcare providers[15,20]. While these problems can be attributed to structural factors such as low medical fees and easy access to care, this study approaches the issue from a frontline ED perspective. We believe that proper triage, based on patient severity, may shorten ED stay times, enhance the quality of emergency care, and address the root of several ongoing challenges[19].

Triage systems are globally utilized to determine treatment priorities based on a standardized five-level severity scale. Systems such as the Emergency Severity Index in the United States, the Canadian triage and acuity scale (CTAS), the Australian triage scale (ATS), and the Manchester triage system (MTS) in the United Kingdom have been widely adopted. In Korea, a modified version of CTAS, known as the Korean triage and acuity scale (KTAS), has been implemented nationwide since 2016[18]. KTAS categorizes patients into five levels, with levels 1 and 2 indicating the highest severity and requiring immediate or urgent medical intervention.

Traumatic brain injury (TBI) is a major public health concern in Korea and worldwide, leading to significant mortality, severe neurological sequelae, and considerable socioeconomic burden[17]. Therefore, early identification of high-risk patients, particularly those with a higher risk of mortality, is crucial for improving clinical outcomes. While TBI patients in Korea are currently assessed using KTAS, there is limited research on the validity of KTAS in predicting in-hospital mortality specifically for TBI cases. One study showed that lower KTAS levels were associated with higher 30-day mortality for severe trauma patients[13]. However, this study is a single-center, retrospective study involving overall trauma cases rather than being limited to brain injury, which may limit the ability to draw specific conclusions regarding TBI. The objective of this study is to assess the discriminatory performance of the KTAS when applied as a prognostic modifier for evaluating clinical severity and outcomes in patients with TBI.

MATERIALS AND METHODS

Ethics approval and informed consent

This study was approved by the Institutional Review Board (IRB No. 2023-03-002). Given the retrospective design and the use of fully de-identified data obtained from the National Emergency Department Information System (NEDIS), the requirement for informed consent was waived by the Board.

Study design and data source

This study was designed as a retrospective cohort study utilizing data from the NEDIS collected between January 2018 and December 2020. NEDIS is a nationwide database that collects detailed information from emergency medical centers (EMCs) across Korea. The NEDIS, which was established in 2016 as a registry involving >95% of EMCs or institutions in Korea, stores nationwide administrative data. The database in-

Table 1. Korean triage and acuity scale

KTAS level	Definition	Related condition
1 (resuscitation)	Condition poses a threat to the patient's life or extremities	Cardiac arrest, major trauma associated with shock, severe respiratory failure, severely decreased mentation (GCS, 3–8)
2 (emergent)	Condition has the potential to put the patient's life, limbs, or body function at risk	Moderate respiratory failure, hematemesis, symptomatic hypertension (SBP >220 or DBP >130), moderately decreased mentation (GCS, 9–13), fever (BT >38°C, SIRS >3, or SIRS >2 with suspected infection), severe chest pain, abdominal pain (NRS >7), severe headache, major trauma
3 (urgent)	Condition can eventually lead to serious complications	Mild respiratory failure, asymptomatic hypertension (SBP >220 or DBP >130), vomiting and/or nausea (mild dehydration), moderate abdominal pain (NRS, 4–7), moderate headache (NRS, 4–7), non-controllable bloody diarrhea
4 (less urgent)	Condition is associated with age, pain, or other related patient complications	Confusion, symptom of urinary infection, constipation (NRS, <4), mild pain (NRS, <4)
5 (non-urgent)	Condition is derived from a chronic problem	Mild diarrhea, bite, dressing, drug prescriptions

KTAS : Korean triage and acuity scale, GCS : Glasgow coma scale, SBP : systolic blood pressure, DBP : diastolic blood pressure, BT : body temperature, SIRS : systemic inflammatory response syndrome, NRS : numeric rating scale

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cludes a wide range of patient data in terms of emergency care, such as demographic information, KTAS, clinical characteristics, and discharge outcomes. The comprehensive nature of NEDIS allows for large-scale analysis of patient trends and clinical outcomes in emergency settings, making it an ideal data source for evaluating the predictive validity of the KTAS in patients with acute TBI. Upon admission to the emergency center, all TBI patients were evaluated and categorized according to the KTAS. KTAS is a five-level triage system used in Korea to assess the severity of a patient's condition and the urgency of required medical intervention. Level 1 represents the most critical cases requiring immediate resuscitation, while level 5 represents non-urgent cases that can be managed with minimal intervention (Table 1). In this study, the data included two KTAS triage : the initial KTAS by nurses (81.5%) and advanced emergency medical technician (14.6%) assigned at the time of ED arrival and the modified KTAS after physical evaluation.

Inclusion and exclusion criteria

Patients were eligible for inclusion in the study if they had a primary diagnosis of acute TBI, defined by the International Classification of Diseases, 10th revision (ICD-10) codes S06.0 to S06.9. The inclusion criteria were ICD-10 discharge codes S06.0 (cerebral concussion), S06.1 (traumatic cerebral edema), S06.2 (diffuse cerebral injury), S06.3 (focal cerebral injury), S06.4 (traumatic epidural hemorrhage), S06.5 (traumatic subdural hemorrhage), S06.6 (traumatic subarachnoid hemorrhage), S06.7 (intracranial injury with persistent coma), S06.8 (other intracranial injuries), or S06.9 (unclassified intracranial injuries) To ensure that the study focused on acute cases, only patients who were admitted to the neurosurgical department through the emergency center within 24 hours of the initial injury were included. NEDIS data are collected on an ED visit-episode basis; therefore, by applying these patient inclusion criteria, we aimed to minimize the possibility of duplicate counting.

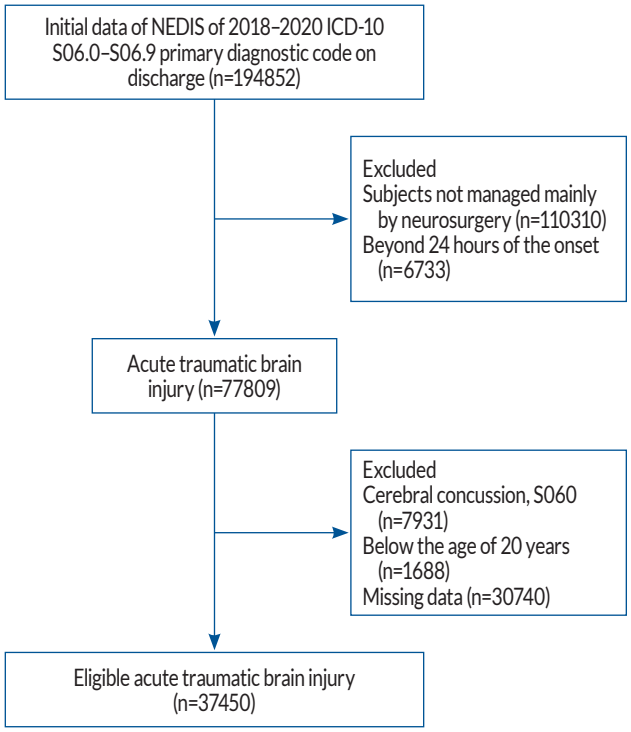

Fig. 1. Inclusion and exclusion of the National Emergency Department Information System (NEDIS) data of 2018–2020. ICD-10 : International Classification of Diseases, 10th revision.

Several exclusion criteria were applied to refine the study population. Patients under the age of 20 were excluded to focus on the adult population, as the clinical characteristics and outcomes of pediatric TBI patients may differ significantly from those of adults. Cerebral concussion (S060) cases were excluded from the study, as this diagnosis typically reflects a milder form of TBI, involving transient functional disturbances rather than direct structural damage to brain tissue, and is therefore less likely to necessitate intensive neurosurgical management. Including such cases could dilute the primary objective of this study, which is to evaluate the predictive performance of KTAS in patients with moderate-to-severe TBI.

Furthermore, patients with missing data or incomplete medical records were excluded to maintain the accuracy and integrity of the analysis. Finally, patients admitted beyond 24 hours after the onset of injury were excluded, as delayed admissions could reflect different clinical courses or healthcare-seeking behaviors that might confound the analysis. The objective of this study was to evaluate the validity of the KTAS as a predictive tool during the acute phase following TBI. To align with this purpose, data recorded beyond 24 hours after injury were excluded from the analysis, as they were considered inconsistent with the study objectives. Additionally, patients who were not primarily managed by the neurosurgical department were excluded, as their clinical management and outcomes might differ from those under specialized neurosurgical care (Fig. 1).

Primary and secondary endpoint

The primary endpoint of the study was in-hospital mortality. This result was selected to reflect the short-term clinical impact

of initial triage decisions and the severity of TBI upon admission. Secondary endpoint included the need for craniotomy or craniectomy, which served as a marker for the severity of intracranial injury and the need for urgent surgical intervention. These results provided a comprehensive assessment of both short-term survival and the broader clinical impact of KTAS-based triage in TBI patients.

Statistical analysis

Median values were used in 5-year ages, vital signs such as systolic blood pressure (SBP), pulse rate, body temperature, arterial O_2 saturation. Comparisons between survival and death were conducted using the Mann-Whitney U test for continuous variables and the chi-square test for categorical variables. Univariate logistic regression analyses for in-hospital mortality were performed for 5-year ages, sex, injury mechanisms, mode of admission, vital signs, response on admission, KTAS 1 and KTAS 2 and craniotomy or craniectomy, respectively. To identify independent predictors of in-hospital mortality, binary multiple logistic regression analyses were performed for multiple confounding variables including 5-year ages, sex, injury mechanisms, mode of admission, vital signs, arterial O_2 saturation, response on admission, initial KTAS, modified KTAS and craniotomy or craniectomy. Response on admission, initial KTAS and modified KTAS were performed in the different model of multivariate regression analysis, respectively because of the possibility of multicollinearity. Non-adjusted and adjusted odds ratio (OR) and 95% confidence interval (CI) were expressed. Predictive performance of craniotomy or craniectomy, initial KTAS and modified KTAS was evaluated using receiver operating characteristic (ROC) curves with calculation of the area under the curve (AUC) and 95% CIs. A p-value of <0.05 was considered statistically significant, and all analyses were conducted using SPSS version 20 (IBM Corp., Armonk, NY, USA)

RESULTS

Patient characteristics by outcome

A total of 194852 patients with TBI were initially identified from the NEDIS database. After applying the inclusion and exclusion criteria, 37450 patients with acute TBI were included in the final analysis. The overall in-hospital mortality among patients with acute TBI was 11.5%, indicating that nearly one in 10 patients with acute TBI did not survive beyond the first month after admission. The median 5-year age of the included patients was between 65 and 69 years (interquartile range, 55–79 years), highlighting that older adults constituted a significant portion of the study population. Among the included patients, 69.1% were male, suggesting that men are more likely to suffer from acute TBI.

Regarding the mechanism of injury, slipping down was the most common cause, accounting for 24.6% of cases. Traffic accidents (including car accident, bike accident, motorcycle accident, and pedestrian traffic accident) account for 25.0%, surpassing 24.6% of slipping down, followed by falls (17.9%), struck (6.4%), others (1.6%), and unknown (24.5%).

Among the documented causes of death, slipping down accounted for 20.0% of fatalities, whereas traffic accidents—including motor vehicle, bicycle, motorcycle, and pedestrian incidents—comprised 26.6%. With regard to mode of admission, 67.1% of patients were admitted directly to the ED, 32.3% were transferred from other hospitals, and 0.6% were referred from outpatient departments. The death were more likely to have been admitted directly (71.2% vs. 66.6%; p<0.001). Initial vital signs upon ED arrival showed that non-survivors had higher median SBP (150 vs. 140 mmHg; p<0.001), higher median pulse rate (87 vs. 82 beats per minute; p<0.001). Response on admission showed stark differences between groups. Among non-survivors, only 17.6% were alert on admission, compared to 66.9% of survivors. Conversely, painful response (44.2% vs. 14.2%) and unresponsiveness (24.5% vs. 2.3%) were significantly more prevalent among death (p<0.001).

Additionally, initial KTAS was classified upon arrival at the emergency room, while modified KTAS indicates retriage after physical examination, with modified KTAS being conducted on 35961 patients (96%) overall. The KTAS classifications showed distinct trends according to outcomes. In the initial KTAS, 8.2% of patients were classified as level 1, 27.9% as level 2, 48.1% as level 3, 15.0% as level 4, and 0.8% as level 5. After physician re-evaluation, the modified KTAS showed a shift : 8.7% were classified as level 1, 31.5% as level 2, 54.6% as level 3, 4.9% as level 4, and 0.3% as level 5. Craniotomy or craniectomy was performed in 9.8% of all patients, with a significantly higher proportion among non-survivors (23.5% vs. 8.0%; p<0.001).

Table 2 provides a detailed summary of the baseline characteristics and clinical features of the study population.

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Table 2. The baseline data and clinical features of 37450 patients with acute traumatic brain injury

Variable	Total (n=37450)	Survival (n=33132)	Death (n=4318)	*p*-value
Age (years)	65–69 (55–59, 75–79)	65–69 (50–54, 75–79)	70–74 (55–59, 80–84)	<0.001
Male	25894 (69.1)	22789 (68.8)	3105 (71.9)	<0.001
Modes of injury				<0.001
Car accident	2143 (5.7)	1996 (6.0)	147 (3.4)	
Bike accident	1372 (3.7)	1207 (3.6)	165 (3.8)	
Motorcycle accident	2639 (7.0)	2333 (7.0)	306 (7.1)	
Pedestrian traffic accident	3203 (8.6)	2672 (8.1)	531 (12.3)	
Fall	6712 (17.9)	6954 (18.0)	758 (17.6)	
Slipping down	9216 (24.6)	8353 (25.2)	863 (20.0)	
Struck	2390 (6.4)	2208 (6.7)	182 (4.2)	
Others or unknown	9775 (26.1)	8409 (25.4)	1366 (31.6)	
Mode of admission				<0.001
Direct	25140 (67.1)	22064 (66.6)	3076 (71.2)	
Transfer from other hospitals	12082 (32.3)	10856 (32.8)	1226 (28.4)	
Referred from OPD or others	228 (0.6)	212 (0.6)	16 (0.3)	
Vital signs				
SBP (mmHg)	140 (124–160)	140 (124–160)	150 (123–176)	<0.001
Pulse rate (beats/min)	83 (72–94)	82 (72–94)	87 (72–102)	<0.001
Body temperature (°C)	36.5 (36.2–36.9)	36.5 (36.2–36.9)	36.4 (36.0–36.8)	<0.001
Arterial O_2 saturation (%)	98 (96–99)	98 (96–99)	97 (94–99)	<0.001
Response on admission				
Alert	22923 (61.2)	22162 (66.9)	761 (17.6)	<0.001
Verbal response	6106 (16.3)	5513 (16.6)	593 (13.7)	
Painful response	6599 (17.6)	4692 (14.2)	1907 (44.2)	
Unresponsive	1822 (4.9)	765 (2.3)	1057 (24.5)	
Initial KTAS				
Level 1	3084 (8.2)	1746 (5.3)	1338 (31.0)	<0.001
Level 2	10441 (27.9)	8575 (25.9)	1866 (43.2)	
Level 3	17997 (48.1)	17088 (51.6)	909 (21.1)	
Level 4	5628 (15.0)	5437 (16.4)	191 (4.4)	
Level 5	300 (0.8)	286 (0.9)	14 (0.3)	
Modified KTAS	35961	31818	4143	
Level 1	3126 (8.7)	1757 (5.5)	1369 (33.0)	<0.001
Level 2	11326 (31.5)	9472 (29.8)	1854 (44.8)	
Level 3	19643 (54.6)	18777 (59.0)	866 (20.9)	
Level 4	1748 (4.9)	1696 (5.3)	52 (1.3)	
Level 5	118 (0.3)	116 (0.4)	2 (0.0)	
Craniotomy or craniectomy	3655 (9.8)	2642 (8.0)	1013 (23.5)	<0.001
Discharge destination				
Normal discharge	20404 (54.5)	20404 (61.6)	0 (0.0)	
Transfer	11434 (30.5)	11434 (34.5)	0 (0.0)	
In-hospital mortality	4318 (11.5)	0 (0.0)	4318 (100.0)	
Others	1294 (3.5)	1294 (3.9)	0 (0.0)	

Values are presented as median (Q1, Q3) or number (%). Compared to the initial KTAS, the modified KTAS was performed in 35961 patients, accounting for 96%, while 4% had no data available. OPD : outpatient department, SBP : systolic blood pressure, KTAS : Korean triage and acuity scale

The clinical characteristics by KTAS level

Detailed clinical characteristics of KTAS 1 by level are thoroughly described in Table 3. The median 5-year age of patients in level 1 was 60–64 years, whereas patients in levels 2–5 had a median age of 65–69 years. Male sex was more frequently observed in higher severity groups (74.5% in level 1 vs. 71.0% in level 5; $p<0.001$). The response on admission showed a clear association with initial KTAS level 1 : among level 1 patients, 57.7% exhibited a pain response state, and 35.1% were unresponsive, whereas 80.0% of level 3 patients were alert ($p<0.001$). ICU admission was highest in level 1 (95.7%), followed by level 2 (84.8%), and progressively decreased in level 3 (61.5%), level 4 (51.0%), and level 5 (49.0%) ($p<0.001$). Craniotomy or craniectomy were highest in level 1 (22.6%) and remained relatively high in level 2 (15.4%), but decreased significantly in lower levels ($p<0.001$). In-hospital mortality was highest in level 1 (31.0%) and level 2 (43.2%), and declined markedly in lower levels : 21.1% in level 3, 4.4% in level 4, and 0.3% in level 5 ($p<0.001$). The craniotomy or craniectomy and in-hospital mortality by initial KTAS level are neatly summarized in Fig. 2.

The independent predictors for in-hospital mortality

In the regression analysis for in-hospital mortality, several clinical and demographic variables were found to be significant predictors in Table 4. After adjustment, significant predictors with an OR greater than 2 included advanced age (≥80 years : OR, 4.76; 95% CI, 3.98–5.70), low SBP (<90 mmHg : OR, 2.24;

Table 3. Clinical features for each level of initial Korean triage and acuity scale

Variable	Initial Korean triage and acuity scale					*p*-value
	Level 1 (n=3084)	Level 2 (n=10441)	Level 3 (n=17997)	Level 4 (n=5628)	Level 5 (n=300)	
Age (years)	60–64 (50–54, 70–74)	65–69 (50–54, 75–79)	65–69 (55–59, 75–79)	65–69 (55–59, 75–79)	65–69 (55–59, 75–79)	<0.001
Male	2297 (74.5)	7631 (73.1)	12174 (67.6)	3579 (63.6)	213 (71.0)	<0.001
Response on admission						<0.001
Alert	98 (3.2)	3262 (31.2)	14393 (80.0)	4932 (87.6)	238 (79.3)	
Verbal response	122 (4.0)	2794 (26.8)	2615 (14.5)	541 (9.6)	34 (11.3)	
Painful response	1781 (57.7)	3736 (35.8)	902 (5.0)	152 (2.7)	28 (9.3)	
Unresponsive	1083 (35.1)	649 (6.2)	87 (0.5)	3 (0.1)	0 (0.0)	
ICU admission	2950 (95.7)	8880 (84.8)	11062 (61.5)	2872 (51.0)	147 (49.0)	<0.001
Craniotomy or craniectomy	698 (22.6)	1611 (15.4)	1085 (6.0)	252 (4.5)	9 (3.0)	<0.001
In-hospital mortality	1338 (43.4)	1866 (17.9)	909 (5.1)	191 (3.4)	14 (4.7)	<0.001

Values are presented as median (Q1, Q3) or number (%). ICU : intensive care unit

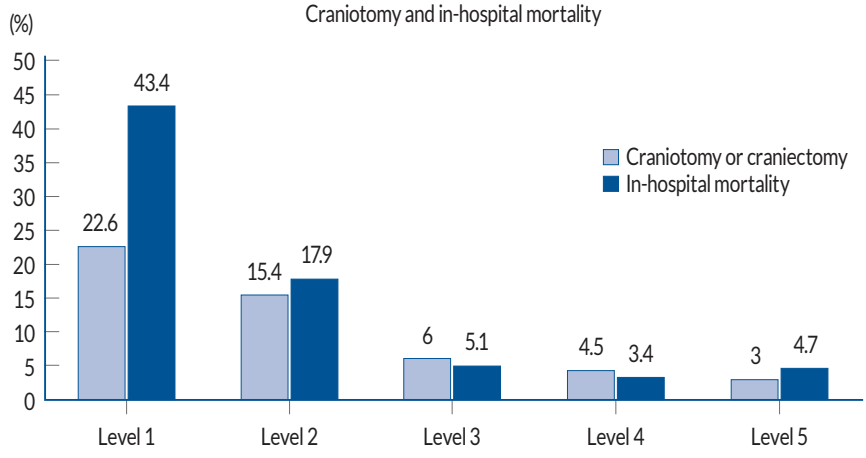

Fig. 2. Craniotomy or craniectomy and in-hospital mortality according to initial Korean triage and acuity scale.

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Table 4. Univariate and multiple regression analysis for in-hospital mortality

Variable	Non-adjusted		Adjusted	
	OR (95% CI)	*p*-value	OR (95% CI)	*p*-value
Age				
20–39 years	Reference		Reference	
40–59 years	1.48 (1.23–1.73)	<0.001	1.61 (1.35–1.91)	<0.001
60–79 years	1.89 (1.63–2.19)	<0.001	2.60 (2.20–3.08)	<0.001
≥80 years	2.88 (2.46–3.36)	<0.001	4.76 (3.98–5.70)	<0.001
Male	1.16 (1.08–1.25)	<0.001	1.24 (1.14–1.34)	<0.001
Injury mechanisms				
Car accident	Reference		Reference	
Bike accident	1.86 (1.47–2.34)	<0.001	1.57 (1.21–2.04)	<0.001
Motorcycle accident	1.78 (1.45–2.19)	<0.001	1.47 (1.17–1.83)	0.001
Pedestrian traffic accident	2.70 (2.23–3.27)	<0.001	1.90 (1.54–2.34)	<0.001
Fall	1.73 (1.44–2.08)	<0.001	1.49 (1.22–1.82)	<0.001
Slipping	1.40 (1.17–1.68)	<0.001	1.54 (1.26–1.87)	<0.001
Struck	1.12 (0.89–1.40)	0.328	1.17 (0.92–1.50)	0.210
Transfer from other hospitals	0.81 (0.76-0.87)	<0.001	0.72 (0.67-0.78)	<0.001
SBP				
<90 mmHg	5.92 (4.96–7.08)	<0.001	2.24 (1.83–2.74)	<0.001
90–109 mmHg	1.51 (1.31–1.74)	<0.001	1.21 (1.03–1.41)	0.019
110–129 mmHg	Reference		Reference	
130–149 mmHg	0.93 (0.84–1.04)	0.194	0.90 (0.80–1.01)	0.067
150–169 mmHg	1.29 (1.16–1.44)	<0.001	1.08 (0.96–1.21)	0.191
≥170 mmHg	2.49 (2.25–2.76)	<0.001	1.58 (1.42–1.77)	<0.001
Pulse rate				
<60 beats/min	2.30 (2.03–2.62)	<0.001	1.69 (1.46–1.95)	<0.001
60–100 beats/min	Reference		Reference	<0.001
>100 beats/min	2.23 (2.07–2.40)	<0.001	1.51 (1.39–1.64)	
Body temperature, <35°C	3.76 (3.24–4.36)	<0.001	1.94 (1.64–2.30)	<0.001
Arterial O_2 saturation, <90%	5.35 (4.73–6.06)	<0.001	1.98 (1.71–2.28)	<0.001
Response on admission*				
Alert	Reference		Reference	
Verbal response	3.13 (2.80–3.50)	<0.001	2.91 (2.60–3.26)	<0.001
Painful response	11.84 (10.82–12.95)	<0.001	9.83 (8.93–10.83)	<0.001
Unresponsive	40.24 (35.77–45.27)	<0.001	32.71 (28.77–37.20)	<0.001
Initial KTAS*				
Level 1	15.66 (9.11–26.90)	<0.001	10.33 (5.96–17.88)	<0.001
Level 2	4.46 (2.60–7.62)	<0.001	3.52 (2.04–6.07)	<0.001
Level 3	1.09 (0.63–1.87)	0.763	0.98 (0.57–1.70)	0.946
Level 4	0.72 (0.41–1.25)	0.242	0.67 (0.38–1.17)	0.157
Level 5	Reference		Reference	
Modified KTAS*				
Level 1	45.19 (11.15–183.19)	<0.001	25.96 (6.37–105.76)	<0.001
Level 2	11.35 (2.80–45.98)	<0.001	7.77 (1.91–31.61)	0.004
Level 3	2.68 (0.66–10.84)	0.168	2.13 (0.52–8.67)	0.291
Level 4	1.78 (0.428–7.39)	0.428	1.53 (0.37–6.38)	0.562
Level 5	Reference		Reference	
Craniotomy or craniectomy	3.54 (3.30–3.87)	<0.001	2.44 (2.23–2.68)	<0.001

*Response on admission, initial KTAS and modified KTAS were performed in the different model of multivariate regression analysis, respectively. OR : odds ratio, CI : confidence interval, SBP : systolic blood pressure, KTAS : Korean triage and acuity scale

95% CI, 1.83–2.74), response on admission was a strong predictor, with unresponsiveness associated with a 32.71-fold increased risk of mortality (95% CI, 28.77–37.20). Painful response increased the risk by 9.83 times (95% CI, 8.93–10.83), and verbal response increased the risk by 2.92 times (95% CI, 2.60–3.26). The KTAS levels were also strong predictors of in-hospital mortality. For initial KTAS, level 1 was associated with an adjusted OR of 10.33 (95% CI, 5.96–17.88) and level 2 with an OR of 3.52 (95% CI, 2.04–6.07) compared to level 5. For modified KTAS, the adjusted OR for level 1 was 25.96 (95% CI, 6.37–105.76) and for level 2, 7.77 (95% CI, 1.91–31.61) compared to level 5. Craniotomy or craniectomy also showed an OR of 2.44 (95% CI, 2.23–2.68) compared to the group that did not undergo surgery.

ROC analysis

The predictive validity of KTAS for clinical outcomes was assessed using ROC analysis. Initial KTAS had an AUC of 0.750 (95% CI, 0.742–0.758) for predicting in-hospital mortality and 0.666 (95% CI, 0.657–0.676) for predicting the need for craniotomy or craniectomy. Modified KTAS showed similar predictive performance, with an AUC of 0.751 (95% CI, 0.743–0.760) for mortality and 0.669 (95% CI, 0.660–0.679) for surgical intervention, all p-values <0.001. These findings underscore that both initial and modified KTAS classifications provide robust predictive capability for mortality, while the predictive power for surgical intervention was comparatively lower.

DISCUSSION

This study represents the first large-scale analysis evaluating the clinical validity of the KTAS in patients with TBI. According to the results, KTAS levels 1 and 2 were identified as strong predictors of short-term mortality in patients with TBI. Moreover, the study highlights that the predictive validity of KTAS is further enhanced when retriage is performed based on the patient's evolving clinical condition. While KTAS alone may not be sufficient to predict the need for surgical intervention, it effectively reflects the overall severity of the patient's condition and offers valuable utility for early risk stratification and clinical decision-making in the management of TBI.

In addition, these findings suggest that the principle of repeated evaluation in triage systems can have significant implications for the future development of triage protocols, including but not limited to KTAS. Specifically, the results underscore that in triage systems designed for rapid assessment, repeated re-evaluation is crucial for ensuring reliable and valid clinical predictions. This insight is not limited to KTAS but extends to other triage systems that prioritize rapid assessment, emphasizing the importance of dynamic, ongoing evaluation in acute care settings.

Triage prioritization systems are effective in overcrowded situations, and such systems are considered essential in scenarios of extreme overcrowding—such as wartime or disaster situations. Even in war situation or national disaster situation, mass casualty training is conducted to determine how to perform triage effectively under such circumstances[6,7,14]. Efficient patient triage in the emergency medical system is an important tool for improving the efficiency of medical care and effectively enhancing patient outcomes[21]. However, triage systems may not always accurately reflect the severity of all patients visiting the ED. Therefore, since 2016, KTAS, which has been standardized across EMCs in Korea, requires validity evaluation. In particular, we aimed to evaluate whether the KTAS is appropriate for distinguishing between emergency and non-emergency cases in patients with TBI.

In trauma patients, the Injury severity score (ISS), introduced internationally by Baker and others, is commonly used to assess severity based on anatomical injury. An ISS of 16 or higher is generally considered a severe trauma[1]. In addition, while ISS reflects only anatomical severity, the Trauma and injury severity score (TRISS) includes physiological status and age as additional factors[2]. It has also been reported that patients with ISS ≥25 (OR, 122.6; 95% CI, 89.13–168.77) and those with ISS between 16–24 have higher mortality compared to those with ISS <16[11]. Furthermore, in patients with severe trauma (ISS ≥16), one study found that compared to KTAS level 3, KTAS level 1 showed a hazard ratio of 4.868 for 30-day mortality (95% CI, 2.341–10.119)[13]. The ultimate goal of these studies is to demonstrate that the KTAS classification reflects the severity of trauma in severe trauma patients.

It remains unclear which acuity scoring tools are most closely associated with the severity, prognosis, and mortality of patients with TBI. According to Cooke et al.[5], among 131 patients with severe TBI defined as having an ISS of 16 or higher, the Glasgow coma scale (GCS), ISS, and TRISS were evaluated in relation to Glasgow outcome scale (GOS) and mortality. TRISS

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showed a stronger correlation with GOS and mortality than GCS, although the difference was not statistically significant. In another study by Najafi et al.[16], multiple acuity scoring tools were analyzed for their association with 24-hour mortality in TBI patients. A total of 185 TBI patients were included, and various indices—Revised trauma score (RTS), National early warning score (NEWS), ISS, Shock index (SI), Modified SI (MSI), and TRISS—were assessed. Hospital RTS, prehospital NEWS, and patient age were found to be significant predictors of 24-hour mortality, and the model explained approximately 51.2% of the variance in survival outcomes. However, many of these tools, such as ISS, TRISS, RTS, NEWS, SI, and MSI, are complex and require multiple parameters, making them difficult to apply immediately upon ED arrival. Even the relatively simple GCS can produce inconsistent results depending on the examiner's level of training. In contrast, KTAS has the advantage of allowing faster assessment compared to other parameters. However, while the speed and validity of such triage systems are indeed important, problems can arise in reliability if consistency varies among evaluators. Therefore, to ensure the quality of the KTAS system, classification qualifications are granted only to physicians, nurses, and level 1 emergency medical technicians who have worked in ED for at least 12 months within the past 5 years[10]. Accordingly, if KTAS reliably reflects severity and prognosis, particularly in patients with TBI, despite being simpler than other triage systems, it may serve as an efficient and practical alternative.

Patients with TBI often present to the ED with relatively mild clinical symptoms compared to other critical conditions; however, they may experience abrupt clinical deterioration. This tendency is particularly evident in older patients, underscoring the importance of promptly assessing airway, breathing, and circulation, as well as initiating appropriate medical stabilization to prevent secondary ischemic brain injury due to circulatory compromise[8]. Therefore, a detailed and accurate analysis of the unique clinical characteristics of TBI patients is essential for improving early triage accuracy.

In this study, analysis of mortality according to injury mechanism in Table 2 showed that the mortality from slipping was unexpectedly higher than that of high-energy trauma. Although slipping was less common than traffic accidents overall, it accounted for a disproportionately high share of fatalities (20.0% vs. 26.6%), indicating that even low-energy trauma may lead to severe outcomes, particularly in older adults. This high mortality in slipping is likely due to the vulnerability of the elderly population. Older adults often present with mild initial symptoms after a slip-down but can experience progressive neurological deterioration due to diminished physiologic reserves, underlying comorbidities, or the use of antithrombotic medications. In the analysis of Table 4, the in-hospital mortality OR for slipping was 1.54 times higher than that of the reference group, car accidents, confirming this finding.

However, since a considerable proportion was classified as "Others or unknown" in the injury mechanism category, the mortality related to slipping may have been relatively overestimated. Additionally, in this large population-based dataset (n=37450), even small absolute differences in physiologic parameters such as SpO_2 reached statistical significance due to high statistical power. For instance, a 1% difference (97% vs. 98%) remained within the normal physiologic range (95–100%) and was unlikely to represent clinically meaningful hypoxemia. Therefore, Table 4 presents SpO_2 using 90% as a cutoff value, and after adjustment, SpO_2 showed an OR of 1.98 with a 95% CI of 1.71–2.28, supporting its relevance only as a descriptive indicator rather than an independent prognostic factor.

KTAS level 2 had a higher mortality rate than KTAS level 1. 21.1% of patients classified as level 3 of initial KTAS and 20.9% of patients classified as level 3 of modified KTAS died. Moreover, even in clinically stable level 4 patients, 191 deaths occurred in initial KTAS and 52 deaths in modified KTAS. Additionally, among patients who were alert on admission, 761 deaths were reported. These patients may have been mis-triaged or experienced rapid clinical deterioration after the initial triage. In the patients with delayed hemorrhage, anticoagulants, antiplatelets or underlying medical conditions in old ages, initial triage was relatively good (level 2), but the actually severe brain damage may be a statistically significant proportion of the patient group. In other words, such outcomes could be explained by cases in which the head injury was minor, but the patients were elderly and had anticoagulants or antiplatelet agents or various underlying diseases. The clinical condition of patients is dynamic and can change rapidly; therefore, before a comprehensive and accurate diagnosis is established, it is difficult to guarantee that a single-time KTAS classification accurately reflects the patient's prognosis. For instance, elderly patients or those with epidural hematoma presenting with a lucid interval or those with increasing delayed intracranial hemorrhage may fall into this category[7]. Furthermore, as elderly pa-

tients tend to have diminished physiologic reserves, they may initially present with mild symptoms following a TBI incident, but their condition may progressively and sequentially deteriorate, ultimately resulting in death. According to Chung et al.[4], the KTAS triage system showed a lower predictive ability for in-hospital mortality in the elderly group, with an ROC value of 0.711 compared to 0.809 in the adult group, indicating diminished predictive performance for mortality in older patients. It appears that the KTAS system tends to underestimate the severity and urgency during the initial triage phase in patients aged 65 and older. This issue is not unique to the KTAS system; similar problems have also been reported in systems based on

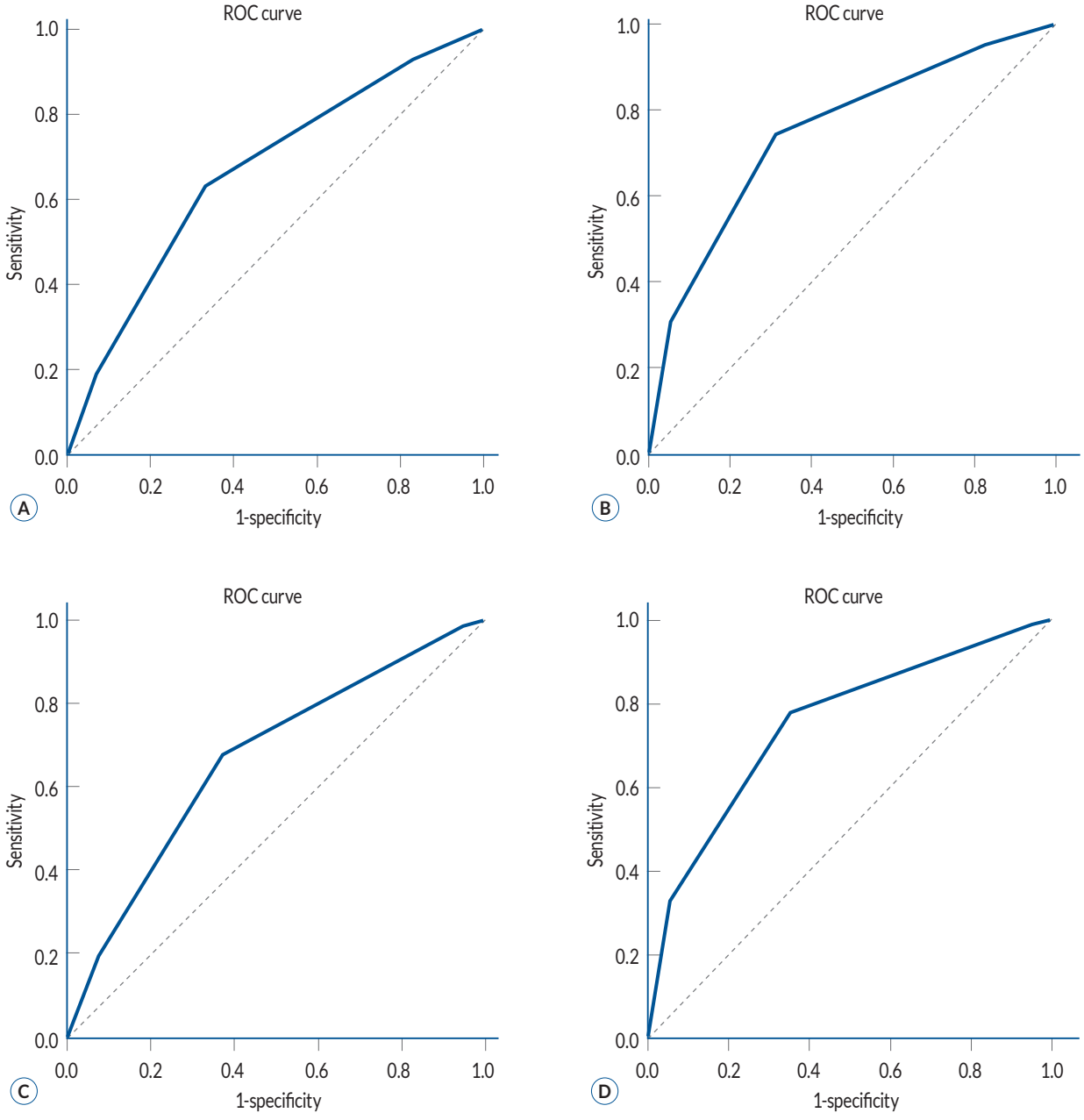

Fig. 3. Receiver operating characteristic curve showing the area under curve (AUC) of Korean triage and acuity scale 1 for craniotomy and in-hospital mortality (A, B), AUC, 0.666 (95% CI, 0.657–0.676) and 0.750 (95% CI 0.742–0.758), respectively, all $p<0.001$) and Korean triage and acuity scale 2 for craniotomy and in-hospital mortality (C, D), AUC, 0.669 (95% CI, 0.660–0.679) and 0.751 (95% CI 0.743–0.760), respectively, all $p<0.001$). ROC : receiver operating characteristic, CI : confidence interval.

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ESI or MTS[3,9,12]. Therefore, based on the evolving clinical situation, supplementary measures such as re-triage at regular intervals after the initial assessment may be necessary. These findings suggests that additional evaluation (re-triage) plays an important role in clinical settings to address concerns regarding the accuracy and reliability of KTAS classification.

Ultimately, initial ED triage systems inherently have cohort-specific limitations when it comes to predicting patient outcomes, especially in elderly patients. Therefore, for outcome prediction in such patients, it may be necessary to use more complex scoring systems, such as RTS, NEWS, TRISS, SI, or MSI, which incorporate various parameters—although these are less suited for rapid triage applications due to their complexity.

Recognizing the necessity of retriage, this study aimed to enhance the reliability of KTAS classification by distinguishing between the initial KTAS classification, which was assigned upon arrival at the ED, and the KTAS classification modified KTAS after physician evaluation and reflection on the patient's clinical course. The analysis showed that 96% of all patients underwent modified KTAS evaluation, indicating that, for the majority of patients, triage was not solely dependent on a single-point assessment but rather involved a retriage process incorporating the patient's evolving clinical condition and the physician's judgment. Importantly, this retriage process was not merely a correction or modification of the initial KTAS classification but a supplementary step that reflected the patient's condition changes and additional clinical considerations following the initial evaluation.

As shown in Fig. 3, both initial and modified KTAS triage had good predictive performance for in-hospital mortality (AUC, 0.750 vs. 0.751), compared to craniotomy or craniectomy (AUC, 0.666 vs. 0.669), suggesting that the KTAS triage process yields more reliable outcome predictions for mortality than surgical intervention in TBI patients. These findings can be attributed to the fact that KTAS system mainly reflects vital signs and consciousness levels, while surgical interventions are not determined by severity alone, but by structural problems in the brain.

Therefore, the findings on the validity of KTAS presented in this study are not limited to a single-point evaluation of KTAS but rather reflect results achieved through repeated assessments and supplementary judgments based on the evolving clinical situation. As previously discussed, this suggests that additional evaluation (retriage) plays an important role in clinical settings to address concerns regarding the accuracy and reliability of KTAS classification.

Additionally, this study excluded patients with mild TBI, specifically those diagnosed with cerebral concussion (S06.0), from the final analysis. As a result, a discrepancy arose between the entire patient population to whom KTAS classification was applied and the study population analyzed. This discrepancy may limit the overall validity assessment of the KTAS system. For example, a patient initially classified as KTAS level 5 but later diagnosed with chronic subdural hematoma was included in the analysis, whereas a patient classified as KTAS level 3 who was ultimately diagnosed with a concussion was excluded. Although KTAS classification was applied to all TBI patients in the emergency setting, the study population was limited, introducing potential bias in assessing the overall accuracy of the KTAS system. Therefore, further research is necessary to evaluate the clinical validity of KTAS classification specifically for KTAS levels 3–5 and mild TBI patients.

According to the results of this study, KTAS levels 1 and 2 were identified as strong predictors of short-term mortality in patients with TBI. Patients classified as initial KTAS level 1 were in the most critical condition and had a 10.33-fold higher risk of in-hospital mortality compared to those classified as level 5. For patients classified as modified KTAS level 1, the risk was even higher, at 25.96 times. Similarly, patients assigned to initial KTAS level 2 had a 3.52-fold increased risk of in-hospital mortality, while those classified as modified KTAS level 2 had a 7.77-fold increased risk. These findings suggest that the KTAS system effectively identifies critically ill TBI patients and demonstrates strong validity in predicting in-hospital mortality. Furthermore, the modified KTAS shows even stronger predictive validity for mortality, indicating that KTAS is more than a simple classification tool—it has value in predicting clinical outcomes for patients with life-threatening traumatic brain injuries.

Furthermore, the predictive performance of KTAS for in-hospital mortality was superior to its ability to predict the need for craniotomy or craniectomy. When evaluating the predictive validity of the modified KTAS alone, The AUC for predicting in-hospital mortality was 0.751, while the AUC for predicting surgical intervention was only 0.669. This discrepancy can be explained by several clinical factors. First, KTAS is fundamentally a rapid triage tool based on physiological parameters. In

contrast, the decision to perform a craniotomy is a highly complex process where multiple clinical, anatomical, and neurological factors are intricately intertwined. Because surgical indications rely heavily on specific neuroimaging findings—such as hematoma volume or midline shift—and detailed neurological assessments, these complex nuances are inevitably not fully reflected in the initial triage phase. Second, patients categorized in the most severe group (KTAS level 1) often present with devastating, irreversible brain injuries or profound hemodynamic instability, rendering them unsuitable for surgical intervention (inoperable). These critical patients contribute significantly to the mortality rate but not to the surgical rate. Finally, many severe TBI cases, including those with diffuse axonal injury, are managed with intensive medical therapies rather than surgical decompression. This implies that KTAS reflects not only the need for surgical treatment but also the overall severity of the patient's condition. While KTAS may not fully capture the necessity for surgical treatment, it effectively reflects the overall clinical severity and prognosis of patients. Accordingly, it holds potential as a valuable instrument in guiding early clinical decision-making. Ultimately, KTAS is not a perfect tool for predicting the need for craniotomy. However, it has value as an initial screening tool for assessing severity and mortality risk. Decisions regarding craniotomy should be made based on KTAS, in conjunction with additional factors such as imaging findings, GCS scores, and input from neurosurgical specialists.

This study has several limitations that should be acknowledged. First, the retrospective design inherently carries the risk of selection and information bias, as patient data were collected from a large administrative database rather than through prospective clinical assessment. Second, the use of the NEDIS database, while comprehensive in its nationwide scope, lacks detailed clinical variables such as GCS scores, radiologic findings, and long-term outcomes such as the GOS or the modified Rankin scale (mRS). This limitation restricts the ability to fully capture the nuances of TBI severity and recovery. Third, the exclusion of patients diagnosed with mild TBI (S06.0, cerebral concussion) introduces a discrepancy between the patient population to whom KTAS classification was applied and the population included in the analysis, potentially limiting the generalizability of the results. Fourth, even when KTAS is administered by experienced healthcare professionals, subjective judgment may influence the classification, and the resulting inter-rater variability could affect its validity. Fifth, NEDIS data is a visit-based registry, there is a possibility of duplicating data due to repeated hospitalizations or inter-hospital transfers. Lastly, while this study focused on in-hospital mortality and surgical intervention as key outcomes, it did not assess long-term functional recovery or quality of life, which are also critical considerations in the comprehensive management of TBI patients. Future research should address these gaps by incorporating long-term functional outcomes and additional clinical variables to more accurately assess the prognostic validity of KTAS.

CONCLUSION

This study demonstrates that KTAS is a valuable tool for early risk stratification in patients with acute TBI, particularly for predicting short-term mortality in critically ill patients. The findings support the use of KTAS as an initial triage tool, but highlight the importance of repeated reassessment (retriage) to ensure accurate clinical decision-making. Further studies are needed to validate KTAS in broader TBI populations and refine its predictive utility for surgical interventions and long-term outcomes.

AUTHORS' DECLARATION

Conflicts of interest

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

Informed consent

This type of study does not require informed consent.

Author contributions

Conceptualization : CJ, BHY; Data curation : CJ; Formal analysis : CJ, BHY; Funding acquisition : CJ; Methodology : CJ; Project administration : CJ, BHY; Visualization : CJ, YKP; Writing - original draft : BHY; Writing - review & editing : DRK, HJC, JHK, HIK ISB

Data sharing

This study used National Emergency Department Information System (NEDIS) data.

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