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The Relationship Between Trauma Scoring Systems and Outcomes in Patients With Severe Traumatic Brain Injury

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Conflict of Interest
The authors have no financial conflicts of
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ABSTRACT

Objective: This study investigated the relationship between trauma scoring systems and outcomes in patients with severe traumatic brain injury (TBI).

Methods: From January 2018 to June 2021, 1,122 patients with severe TBI were registered in the Korean Neuro-Trauma Data Bank System. Among them, 697 patients with data on trauma scoring systems were included in the study. According to the Glasgow Outcome Scale-Extended score, the patients were divided into unfavorable and favorable outcome groups. The abbreviated injury scale (AIS), injury severity score (ISS), revised trauma score (RTS), and trauma and injury severity score (TRISS) were evaluated.

Results: The AIS head score was higher in the unfavorable outcome group than in the favorable outcome group (4.39 vs. 4.06, $p<0.001$). ISS was also higher in the unfavorable outcome group (27.27 vs. 24.22, $p=0.001$). The RTS and TRISS were higher in the favorable outcome group (RTS, 4.74 vs. 5.45, $p<0.001$; TRISS, 48.05 vs. 71.02, $p<0.001$). In comparing the survival and death groups, the ISS was lower in the survival group (25.76 vs. 27.29, $p=0.036$). Furthermore, RTS was higher in the survival group (5.26 vs. 4.54, $p<0.001$), as was TRISS (62.11 vs. 44.91, $p<0.001$).

Conclusion: Trauma scoring systems, including ISS, RTS, and TRISS, provide tools for quantifying posttraumatic risk and can be used to predict prognosis. Among these, TRISS is an indicator of the predicted survival rate and is considered a clinically useful tool for predicting unfavorable and favorable outcomes in patients with severe TBI.

Keywords: Abbreviated injury scale; Glasgow Outcome Scale; Injury severity score; Traumatic brain injury; Treatment outcome

INTRODUCTION

Traumatic brain injury (TBI) occurs in 3 of 1,000 individuals in the United States and is the leading cause of post-traumatic mortality and morbidity.[4] TBI is also common in South Korea and is one of the top ten causes of death, accounting for approximately 3.0% of the total number of deaths.[14] The trauma scoring system is used to quantify the risk of injury after trauma. It can help medical staff communicate by quantifying various complex injuries and is used to prepare guidelines for treatment prioritization. In addition, the trauma

scoring system is useful for predicting patient prognosis.[3,13] Because patients with severe TBI often have high mortality and poor outcomes, predicting their prognosis can be used not only for the treatment process, but also for explanations to the caregiver and feedback on the treatment results. Therefore, we investigated the relationship between trauma scoring systems and outcomes in patients with severe TBI.

MATERIALS AND METHODS

This retrospective study was approved by the Clinical Research Ethics Review Committee of the Gachon University Gil Medical Center (GBIRB2021-303). Because this was a retrospective study, the clinical research ethics review committee waived the need for informed consent.

Patient selection and data analysis

From January 2018 to June 2021, 1,122 patients were enrolled in the Korean Neuro-Trauma Data Bank System (KNTDBS). Among patients with TBI, those with a Glasgow Coma Scale (GCS) scores of ≤8 and ages of 19 years or older were included in the KNTDBS, and those who had previously undergone head surgery were excluded. Among the 1,122 patients, we performed a retrospective analysis of 697 patients with data on trauma scoring systems, including the abbreviated injury scale (AIS), injury severity score (ISS), revised trauma score (RTS), and trauma and injury severity score (TRISS).

We divided the patients into unfavorable and favorable groups according to the outcome at discharge, which was evaluated using the Glasgow Outcome Scale-Extended (GOSE) score. Unfavorable outcomes were defined as GOSE scores of 1–4 points, and favorable outcomes as 5–8 points.

Age, sex, injury mechanisms, initial vital signs, initial pupil response, initial GCS score, diagnosis, and initial Rotterdam computed tomography (CT) score were evaluated as variables to characterize patients with severe TBI. The evaluated vital signs included systolic blood pressure (SBP) and respiratory rate (RR). The most severe diagnosis was determined to be representative of the multiple diagnoses. The representative diagnoses included subdural hematoma (SDH), epidural hematoma (EDH), intracerebral hemorrhage (ICH)/contusion, subarachnoid hemorrhage (SAH), diffuse axonal injury (DAI), and skull fracture. The Rotterdam CT score is composed of a final score of 1–6 that is attained by adding 1 to the sum of the basal cisterns, midline shifts, epidural mass lesions, and intraventricular blood or traumatic SAH scores.[16]

Trauma scoring systems

This study evaluated the trauma scoring systems for AIS, ISS, RTS, and TRISS.

AIS

The AIS divides the body into 9 compartments, and when calculating the ISS, the compartments are integrated and reclassified into 6 regions according to the coding principle. AIS code consists of a 6 digits 'pre-dot' and a one digit 'post-dot.' The pre-dot number contains information about the injury site, and the post-dot number indicates the injury severity. Post-dot numbers are scored on a scale of '1' to '5,' to indicate the severity of the injury, and an injury that is judged to be non-viable is scored as 6 points.[1]

ISS

ISS is the most widely used anatomical scoring system worldwide because of its high association with mortality.[13] The ISS was obtained by assigning an AIS score to each of the 6 body regions and summing the squares of the top 3 highest severity scores. This was obtained using the following equation:

$$ISS = (\text{1st AIS Score})^2 + (\text{2nd AIS Score})^2 + (\text{3rd AIS Score})^2$$

Finally, the result can be graded from 1 for 'least severe' to 75 for 'unsurvivable,' and the higher the score, the higher the mortality rate.[2]

RTS

To overcome the limitations of anatomical scoring systems such as AIS and ISS, in 1981, Champion et al.[7] devised and reported a trauma score by combining physiological data, which was updated in 1989 to create an RTS.[8] RTS is obtained by the following formula: weighing the 'indexed values' of GCS, SBP, and RR with a constant obtained by logistic regression analysis. The scores ranged from 0 to 7.8408 (**TABLE 1**).

$$RTS = 0.9368 \times GCS + 0.7326 \times SBP + 0.2908 \times RR$$

The lower the RTS score, the more severe the physiological derangement; that is, the higher the severity.

TRISS

The TRISS was devised by Boyd et al.[6] in 1987 and considers both anatomical and physiological scoring systems. TRISS includes ISS as an anatomic component, RTS as a physiological component, and patient age as a comorbid component and divides the injury mechanism into blunt and penetrating injuries. The value obtained by the TRISS equation (TRISS score) can be used as a criterion for estimating the probability of survival in trauma patients. The TRISS equation, based on the Major Trauma Outcome Study[9] using the constant value revised in 1995, is as follows:

$$\text{Probability of Survival} = 1/(1 + e^{-b})$$
$$b_{Blunt} = -0.4499 - (0.0835 \times ISS) + (0.8085 \times RTS) - (1.7430 \times AgeIndex)$$
$$b_{Penetrating} = -2.5355 - (0.0651 \times ISS) + (0.9934 \times RTS) - (1.1360 \times AgeIndex)$$

Statistical analysis

Continuous variables were described using means and standard deviations, whereas categorical variables were expressed as frequencies. Continuous variables were compared using an independent t-test, while categorical variables were compared using Pearson's χ^2 test. All tests were performed using a statistical significance criterion of $\alpha = 0.05$. Statistical analyses were performed using SPSS for Windows (version 23.0; IBM Corp., Armonk, NY, USA).

TABLE 1. Indexed values associated with GCS, SBP, and RR used in the calculation of revised trauma score

Value	GCS (point)	SBP (mmHg)	RR (breaths/min)
4	13–15	>89	10–29
3	9–12	76–89	>29
2	6–8	50–75	6–9
1	4–5	1–49	1–5
0	3	0	0

GCS: Glasgow Coma Scale, RR: respiratory rate, SBP: systolic blood pressure.

RESULTS

Patient characteristics

Age, initial pupil response, initial GCS score, diagnosis, and initial Rotterdam CT score significantly differed between the unfavorable and favorable outcome groups. The patients in the unfavorable outcome group were about 10 years older than those of the favorable outcome group (60.4 vs. 50.1 years, $p<0.001$). Furthermore, the reactive pupil response rate was more than half lower in the unfavorable outcome group than in the favorable outcome group (29.5% vs. 64.0%, $p<0.001$). The initial GCS score was also significantly lower in the unfavorable outcome group (4.8 vs. 6.1, $p<0.001$). SDH was the high in both groups; however, the SDH ratio in the unfavorable outcome group was higher than that in the favorable outcome group (62.0% vs. 42.1%, $p<0.001$). The initial Rotterdam CT score was significantly higher in the unfavorable outcome group (4.3 vs. 3.1, $p<0.001$) (**TABLE 2**).

Trauma scoring systems

ISS, RTS, and TRISS showed significant differences between the unfavorable and favorable outcome groups. With respect to the AIS score, the head part was significantly higher in the unfavorable outcome group (4.39) than in the favorable outcome group (4.06, $p<0.001$). There was no difference between the 2 groups in the AIS score of any part other than the head; all were less than 2 points. Furthermore, the ISS was significantly higher in the unfavorable outcome group by approximately 3 points than in the favorable outcome group (27.27 vs. 24.22, $p=0.001$). Also, the RTS and TRISS were significantly higher in the favorable outcome group than in the unfavorable outcome group (RTS, 4.74 vs. 5.45, $p<0.001$; TRISS, 48.05 vs. 71.02, $p<0.001$) (**TABLE 3**).

TABLE 2. Characteristics of patients with severe traumatic brain injury

Characteristics	Total (n=697)	Unfavorable outcome (n=519)	Favorable outcome (n=178)	p-value
Age (years)	57.8±17.4	60.4±17.0	50.1±16.3	<0.001*
Sex, female	172 (24.7)	137 (26.4)	35 (19.7)	0.072
Injury mechanisms				0.832
Traffic accident	317 (45.5)	239 (46.1)	78 (43.8)	
Fall	173 (24.8)	132 (25.4)	41 (23.0)	
Slip down	127 (18.2)	93 (17.9)	34 (19.1)	
Assault	8 (1.1)	6 (1.2)	2 (1.1)	
Etc.†	9 (1.3)	6 (1.2)	3 (1.7)	
Unknown	63 (9.1)	43 (8.2)	20 (11.3)	
Initial vital sign				
Systolic blood pressure	138.8±39.5	140.0±42.2	135.4±30.2	0.120
Respiratory rate	20.5±13.6	20.3±15.1	21.2±7.9	0.458
Initial pupil response				<0.001*
Reactive pupil	267 (38.3)	153 (29.5)	114 (64.0)	
Unilateral unreactive pupil	93 (13.3)	56 (10.8)	37 (20.8)	
Bilateral unreactive pupil	337 (48.4)	310 (59.7)	27 (15.2)	
Initial GCS	5.1±1.7	4.8±1.6	6.1±1.6	<0.001*
Diagnosis				<0.001*
SDH	397 (57.0)	322 (62.0)	75 (42.1)	
EDH	55 (7.9)	23 (4.4)	32 (18.0)	
ICH/Contusion	70 (10.0)	52 (10.0)	18 (10.1)	
SAH	86 (12.3)	64 (12.3)	22 (12.4)	
DAI	69 (9.9)	47 (9.1)	22 (12.4)	
Skull fracture	20 (2.9)	11 (2.2)	9 (5.0)	
Initial Rotterdam CT score	4.0±1.4	4.3±1.3	3.1±1.3	<0.001*

Values are presented as mean ± standard deviation or number (%).
CT: computed tomography, DAI: diffuse axonal injury, EDH: epidural hematoma, GCS: Glasgow Coma Scale, ICH: intracerebral hemorrhage, SAH: subarachnoid hemorrhage, SDH: subdural hematoma.
*Statistically significant difference, $p<0.05$; †It includes being struck by a person or object, buried under an object, and caught in a machine.

ISS, RTS, and TRISS showed significant differences between the survival and death groups. Notably, the ISS was significantly lower in the survival group (25.76) than in the death group (27.29, p=0.036). Furthermore, the RTS was significantly higher in the survival group (5.26) than in the death group (4.54, p<0.001). The TRISS was also significantly higher in the survival group (62.11) than in the death group (44.91, p<0.001) (**TABLE 4**).

In the TRISS comparison between the unfavorable outcome, favorable outcome, survival, and death groups, the scores were higher in the order of favorable outcome, survival, unfavorable outcome, and death group (71.02, 62.11, 48.04, and 44.91, respectively) (**FIGURE 1**).

TABLE 3. Comparison of trauma scoring systems between the unfavorable and favorable outcome groups

Trauma scoring systems	Unfavorable outcome (n=519)	Favorable outcome (n=178)	p-value
AIS			
Head	4.39±0.82	4.06±1.00	<0.001*
Face	0.60±0.95	0.69±0.92	0.273
Chest	1.07±1.37	1.06±1.35	0.949
Abdominal	0.54±1.04	0.48±0.92	0.521
Extremities	0.90±1.25	0.93±1.25	0.816
External	0.36±0.51	0.44±0.51	0.065
ISS	27.27±9.02	24.22±10.71	0.001*
RTS	4.74±1.25	5.45±0.91	<0.001*
TRISS	48.05±25.30	71.02±23.29	<0.001*

Values are presented as mean ± standard deviation.
AIS: abbreviated injury scale, ISS: injury severity score, RTS: revised trauma score, TRISS: trauma and injury severity score.
*Statistically significant difference, p<0.05.

TABLE 4. Comparison of trauma scoring systems between the survival and death groups

Trauma scoring systems	Survival (n=365)	Death (n=332)	p-value
ISS	25.76±9.79	27.29±9.26	0.036*
RTS	5.26±0.99	4.54±1.31	<0.001*
TRISS	62.11±24.73	44.91±25.97	<0.001*

Values are presented as mean ± standard deviation.
ISS: injury severity score, RTS: revised trauma score, TRISS: trauma and injury severity score.
*Statistically significant difference, p<0.05.
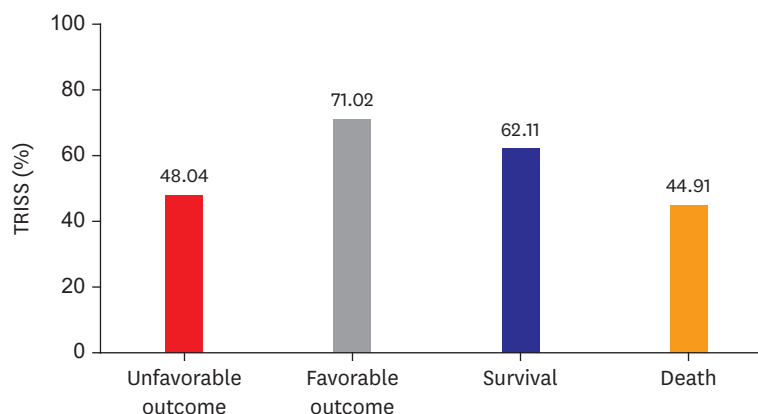
FIGURE 1. Comparison of TRISS values in unfavorable outcome, favorable outcome, survival, and death groups.
TRISS: trauma and injury severity score.

DISCUSSION

Predicting the prognosis of patients with trauma is difficult because of the diverse variables that can affect them. Several studies have identified the risk factors that can affect the prognosis of patients with severe TBI. However, it is impossible to quantitatively determine patient prognosis using risk factors. Steyerberg et al.[21] presented prediction models for 6-month outcomes after TBI using patient admission characteristics from the International Mission for Prognosis and Analysis of Clinical Trials in TBI database. The admission characteristics included age, GCS motor score, pupil size, brain CT findings, and laboratory findings, including glucose and hemoglobin levels. The patient prognosis was calculated using this prediction model, and the prognosis was quantitatively determined using numerical values. However, this prediction model cannot be applied to patients with multiple traumas.

In contrast, the trauma scoring system can be applied to all trauma patients and provides a tool to determine the risk of injury after trauma. Trauma scoring systems can be divided into anatomical (AIS and ISS), physiological (GCS and RTS), and combined (TRISS) categories. We evaluated the outcomes of patients with severe TBI using trauma scoring systems and conducted a study to investigate their clinical usefulness.

Compared with the favorable outcome group, the unfavorable outcome group had older age, more unreactive pupils, lower GCS score, higher proportion of SDH, and higher Rotterdam CT score. These are known risk factors for poor outcomes in patients with TBI.[12,14,16,22] Several studies have reported that hypotension and sex were also related to outcome,[5,10,17,20] but our study did not show a statistically significant difference in these factors between the 2 groups.

In this study, each part of the AIS was analyzed. The face, abdominal, extremity, and external scores were less than one point, and the chest scored an average of one. In patients with severe TBI, damage to parts other than the head did not significantly affect prognosis. The average head score was 4 or higher in both the unfavorable and favorable outcome groups. Most patients with severe TBI can be classified as having severe trauma, with an ISS of 15 or higher. An AIS score of 4 in the head part corresponded to an SDH and EDH thicknesses of 6–10 mm, contusion volume of 30–50 mL, and DAI with loss of consciousness for 6–24 hours. An AIS score of 5 corresponded to an SDH and EDH thickness of 10 mm or greater, contusion volume of 50 mL or greater, DAI with loss of consciousness for more than 24 hours, and brain stem compression, such as through uncal herniation.[11] The average AIS score of the unfavorable outcome group was 4.39, and there were more patients with an AIS score of 5 in the unfavorable outcome group than in the favorable outcome group, which had an average AIS score of 4.06. As a result, if the AIS head score is 5, a high probability of poor prognosis can be expected.

ISS, RTS, and TRISS showed significant differences not only between the unfavorable and favorable outcome groups but also between the survival and death groups. ISS, RTS, and TRISS can be valuable tools for predicting the prognosis of patients with severe TBI. However, it is thought that there will be difficulties in judging the prognosis with ISS and RTS in practice because the difference in absolute values between the 2 groups is insignificant. In the comparison among all groups using TRISS, the unfavorable outcome and death groups showed scores of 50 or less. In other words, in patients with severe TBI with a GCS score of ≤8, a poor prognosis can be predicted when the survival probability derived from TRISS is less than 50%. However, when the probability of survival is greater than 70%, the probability

of a favorable outcome is predicted to be high. As such, TRISS is a value that indicates the predicted survival rate and is intuitive, and the absolute numerical TRISS value difference between groups was significant. Therefore, TRISS is considered more clinically useful than ISS and RTS in prognosis prediction.

However, TRISS has some disadvantages. While it is convenient for calculating predicted survival rates, ISS and RTS values are required to obtain TRISS. An evaluation of the AIS is required to obtain the ISS, and the GCS, SBP, and RR data required to obtain RTS are available in most hospitals. However, it is difficult to obtain AIS data in most hospitals because the AIS evaluations are currently conducted only in trauma centers in South Korea. Of the 18 hospitals enrolled in the KNTDBS, only 6 hospitals evaluated for AIS; therefore, only 697 out of 1,122 patients were included in this study. The AIS is registered by coordinators who have obtained qualifications through clinical experience over a certain period and training courses for a set period. In reality, it is difficult for these personnel to be assigned to hospitals other than trauma centers that treat patients with head trauma. In addition, the reliability of the TRISS value can be increased by reducing missing values only when consistent guidelines and accurate inputs on the GCS, SBP, and RR measurement time are present. To solve these shortcomings, as in the previous large-scale TRISS study, it is important to collect sufficient data and use a statistical technique for missing values.[9,19] It is also necessary to study the applicability of other evaluation methods, such as the International Classification of Diseases Injury Severity score.[18]

This study had some limitations. First, we could not identify the number of patients with TBI who were not registered in the KNTDBS database; therefore, we cannot rule out the possibility of selection bias in our data. In addition, we only included patients from trauma centers who had data on the trauma scoring system from the KNTDBS database. As the treatment system between trauma and the non-trauma centers may differ, different results may be attained when evaluating patients with severe TBI between hospitals. In this study, outcomes were evaluated using GOSE at discharge. However, we could not evaluate long-term outcomes, such as a 3 months–1 year after injury due to insufficient data. In future research, it will be necessary to collect and analyze data on long-term outcomes.

CONCLUSION

Predicting the prognosis of patients with severe head trauma suggests an appropriate treatment plan and enables a more accurate explanation of the treatment results for caregivers. In addition, by comparing the predicted and actual outcomes, the medical staff can receive feedback on the treatment process. The trauma scoring system, including ISS, RTS, and TRISS, is a tool used to quantify post-traumatic risk and predict prognosis. Among these, TRISS is an indicator of the predicted survival rate and is considered a clinically useful tool for predicting unfavorable and favorable outcomes in patients with severe TBI.

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