

Clinical Article



Prognosis Prediction in Severe Traumatic Brain Injury According to Initial Time of Brain Computed Tomography Scan Using the Rotterdam Scoring System

Seunghan Yu ¹, Hyuk Jin Choi ¹, Byung Chul Kim ¹, Mahnjeong Ha ¹,
Kyungbin Kim ², Jung Hwan Lee ¹, and the KNTDB Investigators³

¹Department of Neurosurgery, Medical Research Institute, Pusan National University Hospital, Busan, Korea

²Department of Pathology, Medical Research Institute, Pusan National University Hospital, Busan, Korea

³Korea Neuro-Trauma Data Bank Committee, Korea Neurotraumatology Society, Seoul, Korea



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Address for correspondence:

Jung Hwan Lee

Department of Neurosurgery, Pusan National University Hospital, 179 Gudeok-ro, Seo-gu, Busan 49241, Korea.

Email: medi98@hanmail.net

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ORCID iDs

Seunghan Yu

<https://orcid.org/0000-0003-0086-3204>

Hyuk Jin Choi

<https://orcid.org/0000-0001-9806-8676>

Byung Chul Kim

<https://orcid.org/0000-0002-0439-1382>

Mahnjeong Ha

<https://orcid.org/0000-0001-7358-093X>

Kyungbin Kim

<https://orcid.org/0000-0001-5430-4235>

Jung Hwan Lee

<https://orcid.org/0000-0002-1393-7105>

ABSTRACT

Objective: The Rotterdam scoring system (RSS) is useful for prognosis prediction in patients with severe traumatic brain injury (sTBI). It comprises basal cistern, midline shifting (MLS), epidural hematoma (EDH), and subarachnoid hemorrhage (SAH)/intraventricular hemorrhage (IVH) status. Brain computed tomography (CT) is important to assessing patients with sTBI; however, results often change over time. We aimed to determine whether RSS outcome prediction differs by initial brain CT scan time after the trauma in patients with sTBI.

Methods: We used data from the second Korea Neurotrauma Data Bank, and analyzed 455 patients; RSS, Glasgow Outcome Scale Extended (GOSE) on 6-months, and the CT scan time were obtained. Unfavorable outcomes were defined as a GOSE score of 1–4. Participants were divided into 2 groups according to when brain CT scan was performed (> or ≤ 2 hours after trauma). The relationship between the prognosis of patients with sTBI and RSS score was examined by calculating the odds ratios. Univariate and multivariate analyses were performed.

Results: In both univariate and multivariate analysis, the total RSS and basal cistern status were statistically correlated with prognosis in both groups. EDH and SAH/IVH showed statistically significant difference according to CT scan time. MLS was associated with prognosis in both groups in univariate analysis although not in multivariate analysis.

Conclusion: The total RSS score predicted prognosis 6 months after trauma in patients with sTBI, regardless of CT scan time. However, the prognostic predictive power of each item constituting the RSS varied according to CT scan time.

Keywords: Traumatic brain injury; Tomography, X-ray computed; Mortality; Treatment outcome; Glasgow Outcome Scale

INTRODUCTION

Severe traumatic brain injury (sTBI) is a public health problem owing to high mortality rates and severe disability.^{1,4)} Thus, the prediction of prognosis at the initial evaluation

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Conflicts of Interest

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is important when counseling patients' guardians, distributing medical resources, and establishing a treatment plan.⁶⁾ Brain computed tomography (CT) is the most important radiologic assessment tool for patients with sTBI because it can be performed quickly and easily to check the intracranial condition.⁶⁾ Moreover, scoring systems for CT findings have been developed for prognosis prediction. Maas et al. proposed the Rotterdam scoring system (RSS), which is comprised of basal cistern, midline shifting (MLS), subarachnoid hemorrhage (SAH)/intraventricular hemorrhage (IVH), and epidural hematoma (EDH) status.⁵⁾ Several previous studies have confirmed that RSS can predict prognosis.^{3,5,6)}

However, brain CT findings in patients with sTBI often change over time.^{7,8,12)} Therefore, follow-up scans are performed after the initial brain CT scan to check whether conditions have deteriorated.¹¹⁾ As such, if brain CT findings over time in the same patient are different, it is necessary to determine at which point of brain CT scan taken is more favorable for predicting the prognosis. However, only a few related studies have been conducted.

In this study, we aimed to determine whether outcome prediction of RSS differs according to the initial brain CT scan time after trauma in patients with sTBI. The study utilized data from the second Korea Neurotrauma Data Bank (KNTDB) project.

MATERIALS AND METHODS

Clinical data related to RSS were extracted from the second KNTDB project, which was conducted at 20 hospitals in the Republic of Korea from September 2018 to March 2022. The second KNTDB project enrolled 1,198 patients aged 18 years or older with sTBI defined as a Glasgow Coma Scale (GCS) score of ≤ 8 points. We excluded patients with missing data for Glasgow Outcome Scale Extended (GOSE) score at 6 months after trauma, the RSS score of the initial brain CT scan, time of trauma, initial brain CT scan time.

The following demographic data were collected: age, sex, pupillary reflex, trauma mechanism, initial GCS score, and use of surgical decompression. The patients were divided into two groups according to the initial brain CT scan after trauma based on 2 hours (i.e., ≤ 2 hours or > 2 hours after trauma).

RSS scores calculated as follows: the status of basal cistern status was scored as normal (0), compressed (1), or absent (2); MLS was scored as 0–5 mm (0) or > 5 mm (1); EDH was classified as present (0) or absent (1); and SAH/IVH was classified as absent (0) or present (1). The points of each factor were summed, and added one point to achieve the total RSS score.⁵⁾

The clinical results of interest included neurologic outcomes and mortality. Neurologic outcomes were assessed according to the 6-months GOSE that was comprised of 1) death, 2) vegetative state, 3) lower severe disability, 4) upper severe disability, 5) lower moderate disability, 6) upper moderate disability, 7) lower good recovery, and 8) upper good recovery. For dichotomous variables, we defined unfavorable and favorable outcomes as GOSE scores of 1–4 and 5–8, respectively.¹³⁾ We statistically confirmed the demographic data related to these prognostic factors. In addition, we performed a statistical analysis of the prognostic factors related with RSS score.

The protocol of the second KNTDB project was approved by the Institutional Review Board (IRB) of each hospital, including ours, and the present study was approved by the IRB of our hospital (approval number: 2018-008-105).

All statistical analyses were performed using R software (version 4.0.5; R Foundation for Statistical Computing, Vienna, Austria). For categorical variables, the χ^2 test or Fisher's exact test was performed. For continuous variables, two sample t-test or Wilcoxon rank sum test was performed for two groups, and one-way analysis of variance or Kruskal-Wallis test was performed. The relationship between the prognosis of patients with sTBI and RSS score was evaluated by calculating the odds ratio.

RESULTS

A total of 455 cases were recruited in this study. The mean age was 58 years (range, 18–91 years). The patient characteristics are presented in **TABLE 1**. The patients were divided into two groups according to the initial brain CT scan time after trauma. Comparisons of the clinical features of both groups are presented in **TABLE 1**; a statistically significant difference was identified in age and the trauma mechanism.

The relationship between RSS score and prognosis of patients with sTBI is shown in **TABLE 2**. Univariate analysis confirmed that the total RSS score was significantly correlated with prognosis. However, when each item of the RSS was evaluated separately, basal cistern and MLS status showed good prognosis prediction regardless of the initial brain CT scan time, although EDH and SAH/IVH showed statistically significant difference according to the initial brain CT scan time (**TABLE 3**). Besides RSS score, we identified statistically significant associations

Table 1. Clinical characteristics of 455 patients with severe traumatic brain injury

Variables	Total (%)	CT time ≤ 2 hours (n=324)	CT time > 2 hours (n=131)	p-value
Mean age (years)	58 \pm 17.5	56 \pm 17.5	63.1 \pm 16.4	<0.001
Number of males	292 (74.9)	240 (74.1)	101 (77.1)	0.500
Mean initial GCS	5.08 \pm 1.741	5.11 \pm 1.73	5 \pm 1.78	0.550
Mechanism of trauma				<0.001
Traffic accident	202 (44.4)	164 (50.6)	38 (29)	
Fall	96 (21.1)	70 (21.6)	26 (19.8)	
Slip down	113 (24.8)	64 (19.8)	49 (37.4)	
Other	44 (9.6)	26 (8)	18 (13.7)	
Rotterdam CT score				0.139
1	11 (2.4)	10 (3.1)	1 (1)	
2	49 (10.8)	31 (9.6)	18 (13.7)	
3	93 (20.4)	68 (20.1)	25 (19.1)	
4	124 (27.3)	80 (24.7)	44 (33.6)	
5	103 (22.6)	78 (24.1)	25 (19.1)	
6	75 (16.5)	57 (17.1)	18 (13.7)	
Pupil reactivity				0.477
Both nonreacting	230 (50.5)	166 (51.2)	64 (48.8)	
One reacting	51 (11.2)	39 (12)	12 (9.2)	
Both reacting	168 (37.1)	116 (35.8)	52 (39.7)	
Uncheck	6 (1.3)	3 (1)	3 (2.3)	
Surgical decompression	258 (56.7)	191 (59)	67 (51.1)	0.128
Mortality	277 (60.9)	190 (58.6)	87 (66.4)	0.124
Unfavorable outcome	351 (77.1)	244 (75.3)	107 (81.6)	0.143
Total	455	324 (71.2)	131 (28.8)	

Values are presented as mean \pm standard deviation or number (%).
CT: computed tomography, GCS: Glasgow Coma Scale.

Table 2. Mortality and unfavorable outcome according to Rotterdam computed tomography score

Items	Score	No. of patients	Mortality	Unfavorable outcome
Basal cistern	0	132 (29)	40 (30.3)	77 (58.3)
	1	193 (42.4)	127 (65.8)	153 (79.3)
	2	130 (28.6)	110 (84.6)	121 (93.1)
MLS	0	227 (49.9)	109 (48)	156 (68.7)
	1	228 (50.1)	168 (73.7)	195 (85.5)
EDH	0	91 (20)	50 (55.6)	60 (65.9)
	1	364 (80)	227 (62.4)	291 (79.9)
SAH/IVH	0	107 (23.5)	56 (52.3)	73 (68.2)
	1	348 (76.5)	221 (63.5)	278 (79.9)
Total	1	11 (2.4)	2 (18.2)	4 (36.3)
	2	49 (10.8)	19 (38.8)	26 (53.1)
	3	93 (20.4)	34 (36.6)	63 (67.8)
	4	124 (27.3)	78 (62.9)	96 (77.4)
	5	103 (22.6)	77 (74.8)	90 (87.4)
	6	75 (16.5)	67 (89.3)	72 (96)

Values are presented as number (%).

MLS: midline shifting, EDH: epidural hematoma, SAH/IVH: subarachnoid hemorrhage/intraventricular hemorrhage.

Table 3. Univariate analysis of mortality and unfavorable outcomes of patients with severe traumatic brain injury according to Rotterdam computed tomography score

Items	CT time ≤2 hours				CT time >2 hours			
	Mortality		UO		Mortality		UO	
	OR (95% CI)	p-value	OR (95% CI)	p-value	OR (95% CI)	p-value	OR (95% CI)	p-value
Total	2.05 (1.674–2.510)	<0.001	1.939 (1.561–2.408)	<0.001	1.938 (1.377–2.728)	<0.001	1.943 (1.291–2.923)	0.001
Basal cistern	3.807 (2.677–5.415)	<0.001	3.048 (2.082–4.461)	<0.001	3.728 (2.011–6.913)	<0.001	3.031 (1.466–6.268)	0.003
MLS	3.434 (2.152–5.478)	<0.001	2.636 (1.543–4.504)	<0.001	2.146 (1.026–4.489)	0.043	2.756 (1.086–6.994)	0.033
EDH	1.030 (0.588–1.805)	0.918	1.762 (0.967–3.213)	0.064	2.697 (1.157–6.284)	0.022	3.308 (1.278–8.563)	0.014
SAH/IVH	2.097 (1.240–3.546)	0.006	2.515 (1.438–4.398)	0.001	0.818 (0.349–1.917)	0.644	0.742 (0.253–2.176)	0.587

CT: computed tomography, UO: unfavorable outcome, OR: odds ratio, CI: confidence interval, MLS: midline shifting, EDH: epidural hematoma, SAH/IVH: subarachnoid hemorrhage/intraventricular hemorrhage.

between prognosis and GCS, age, and pupil reactivity. However, there was no statistically significant difference in sex, trauma mechanism, or surgical decompression use (TABLE 4). After adjustments for age, GCS, and pupil reactivity in the multivariate analysis, the prognostic power of the total RSS was good regardless of the initial brain CT scan time. When each item of the RSS was evaluated separately, basal cistern status still show good prognosis prediction regardless of the initial brain CT scan time. EDH and SAH/IVH showed statistically significant differences according to the initial brain CT scan time. In contrast, MLS was identified as having no prognostic predictive value in the multivariate analysis (TABLE 5).

DISCUSSION

In this study, the reason we divided initial brain CT scan time based on 2 hours is that we considered the ideal time of initial brain CT scan in patients with sTBI is within 2 hours after the trauma. First, arriving at an emergency medical center within one hour after the trauma is recommend for critical management of patients with severe trauma.¹⁰⁾ Second, brain CT should be performed and analyzed within one hour of arrival of the patient with sTBI to the emergency room.⁹⁾ Combining these two periods, it can be seen that the brain CT scans within 2 hours after the trauma were the cases in which the intracranial lesion was confirmed as soon as possible after trauma. Therefore, this study was conducted by dividing the patients into two groups based on this 2-hour timeframe.

Table 4. The clinical characteristics related with prognosis

Characteristics	Mortality		p-value	Outcome		p-value
	Alive	Death		Favorable	Unfavorable	
Age	51.8±17.6	62.1±16.2	<0.001	48.7±17.7	60.8±16.5	<0.001
GCS	5.8±1.7	4.6±1.6	<0.001	6.1±1.7	4.8±1.6	<0.001
Pupil			<0.001			<0.001
Both nonreacting	45	185		21	209	
One reacting	23	28		12	39	
Both reacting	109	59		71	97	
Uncheck	1	5		0	6	
Mechanism of trauma			0.058			0.287
Traffic accident	86	116		50	152	
Fall	42	54		23	73	
Slip down	40	73		26	87	
Other	10	34		5	39	
Surgical decompression			0.430			0.995
Yes	105	153		59	199	
No	73	124		45	152	
Sex			0.723			0.596
Male	135	206		80	261	
Female	43	71		24	90	
Total	178	277		104	351	

GCS: Glasgow Coma Scale.

Table 5. Multivariate analysis of mortality and unfavorable outcomes of patients with severe traumatic brain injury (adjusted for age, initial Glasgow Coma Scale, and pupil reactivity) according to Rotterdam computed tomography score

Items	CT time ≤2 hours				CT time >2 hours			
	Mortality		UO		Mortality		UO	
	OR (95% CI)	p-value	OR (95% CI)	p-value	OR (95% CI)	p-value	OR (95% CI)	p-value
Total	1.611 (1.275–2.034)	0.000	1.506 (1.170–1.939)	0.001	1.876 (1.274–2.762)	0.001	1.950 (1.210–3.141)	0.006
Basal cistern	2.690 (1.776–4.075)	0.000	1.936 (1.245–3.011)	0.003	3.699 (1.806–7.577)	0.000	2.891 (1.236–6.761)	0.014
MLS	1.706 (0.951–3.060)	0.073	1.117 (0.579–2.156)	0.741	1.798 (0.759–4.258)	0.182	2.232 (0.761–6.552)	0.144
EDH	0.792 (0.389–1.613)	0.521	1.704 (0.802–3.620)	0.166	2.471 (0.928–6.580)	0.070	3.330 (1.107–10.015)	0.032
SAH/IVH	2.177 (1.111–4.263)	0.023	2.391 (1.202–4.757)	0.013	0.935 (0.363–2.411)	0.890	0.961 (0.293–3.146)	0.947

CT: computed tomography, UO: unfavorable outcome, OR: odds ratio, CI: confidence interval, MLS: midline shifting, EDH: epidural hematoma, SAH/IVH: subarachnoid hemorrhage/intraventricular hemorrhage.

We confirmed the total RSS score as a useful tool in this study based on the predictive power observed in both groups. However, we observed some difference in predictive power when each item of the RSS was analyzed individually. Basal cistern status was statistically correlated with prognosis regardless of the initial brain CT scan time, similar to the total RSS score. However, MLS was confirmed to have predictive power in both groups in the univariate analysis, although it was confirmed to be independent of prognosis in the multivariate analysis, possibly owing to age. Even when MLS >5 mm, the degree of mass effect and intracranial pressure (ICP) elevation may be low in the elderly owing to brain atrophy. Conversely, although the MLS is not severe, the prognosis may be poor due to complications due to old age.

SAH/IVH identified in initial brain CT scans within 2 hours after trauma was statistically related to prognosis, although SAH/IVH identified in an initial brain CT scan obtained >2 hours after trauma was not statistically related. Conversely, EDH identified in the initial brain CT scan within 2 hours after trauma was not related to prognosis, although a partial correlation was confirmed in initial brain CT scans obtained >2 hours after trauma. SAH/IVH may occur immediately after trauma, but over time, hemorrhages originating from other spaces may occur to the subarachnoid or intraventricular space with the flow of cerebrospinal fluid. Thus, if the time between the trauma and initial brain CT scans is long, SAH/IVH can

be seen on brain CT regardless of the trauma severity. Therefore, the results of this study show that SAH/IVH identified by brain CT long after the trauma has a weaker correlation with prognosis. Conversely, EDH is known to have a better prognosis than intradural hematoma.⁵⁾ However, bleeding can occur in the epidural space as well as in the intradural space after the trauma in patients with sTBI; thus the correlation between prognosis and EDH identified in brain CT scans obtained soon after the trauma is considered weak. If increased ICP occurs due to increased hematoma or edema in the intradural space over time after severe trauma, the EDH may not increase further or disappear.²⁾ Conversely, if the pressure in the intradural space is low, the EDH will be maintained, which is associated with low ICP and is thus considered to be related to a good prognosis.

The time the initial brain CT scan obtained showed a statistical relationship with age and trauma mechanism. This may be related to brain atrophy in elderly patients and 'slip down' among trauma mechanisms. Patients involved in high-risk accidents such as traffic accidents are transported to hospital early. However, patients who slip down during everyday life are often transported to the hospital late if acute loss of consciousness does not occur. This 'slip down' is likely to occur among the elderly.¹⁴⁾ Owing to brain atrophy of these elderly, intracranial hematoma and delayed neurologic deterioration may progress slowly. This may contribute to the difference in the time the initial brain CT scan is obtained after trauma.

In this study, surgical decompression and initial brain CT scan time was identified as independent of prognosis in patients with sTBI. However, this result does not mean that patients with sTBI do not require early brain CT scan and surgical decompression. As mentioned earlier, early CT scan is recommended for patients with sTBI.¹⁰⁾ However, in **TABLE 1**, the mortality and unfavorable outcome was high in the group with brain CT scan time of 2 hours or more, but it was confirmed that it was not statistically significant. This is probably because there is no significant difference in the distribution of severity of brain CT scans, that is, RSS. Surgical decompression is known to be helpful in managing ICP in patients with sTBI, although opinions are still divided on its relationship with prognosis.⁴⁾ To confirm the relationship between surgical decompression and prognosis in patients with sTBI, consistently applicable surgical indications must first be established. However, the surgical indications for decompression were not identified in this study. In addition, factors others than those presented in this study should be analyzed. Therefore, further studies are needed to confirm the relationship between surgical decompression and the prognosis of patients with sTBI.

This study has some limitations. First of all, as mentioned earlier, it is thought that surgical decompression had an effect on the prognosis, but correction for this was not made. Second, it is a study that did not collect data prospectively for this study, but only partially collected data from the database. Therefore, there may be bias in the data. The prospective study will be needed to confirm more accurate results in the future.

CONCLUSION

The total RSS score predicted mortality and unfavorable outcomes in patients with sTBI 6 months after trauma, regardless of the initial brain CT scan time after the trauma. However, the prognostic predictive power of each item comprising the RSS differed according to the initial brain CT scan time after the trauma. Therefore, these points should be considered when predicting the prognosis of these patients based on brain CT findings.

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