# The Rotterdam Scoring System Can Be Used as an Independent Factor for Predicting Traumatic Brain Injury Outcomes

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OBJECTIVE: **Predicting outcomes in patients with traumatic brain injury is critically important for making sound clinical decisions. This study aimed at determining the prognostic value of the Rotterdam scoring system to predict early death among these patients.**

MATERIALS AND METHODS: **This study was performed prospectively on 150 patients with traumatic brain injury hospitalized in Shahid Beheshti Hospital, Kashan, Iran. Patients' demographic and clinical characteristics such as age, sex, mechanism of trauma, initial Glasgow Coma Scale score, and accompanying lesions were documented. A brain computed tomography was performed for each patient and scored by use of the Rotterdam system. Patients were monitored for 2 weeks after hospital discharge, and their outcomes were documented. Univariate and multiple logistic regression analysis and prognostic values of Rotterdam system were conducted by SPSS software.**

RESULTS: **Nineteen patients (12.7%) died during the course of the study. The mean age of the dead patients was significantly greater than those who survived ($P = 0.037$). The sensitivity and the specificity of the Rotterdam scoring system at the cutoff score of 4 were 84.2% and 96.2%, respectively. Rotterdam score was significantly correlated with patient outcomes ($P < 0.0001$). Moreover, logistic regression analyses revealed that factors such as age, sex, Glasgow Coma Scale score, and Rotterdam score significantly contributed to patient outcomes.**

CONCLUSIONS: **Rotterdam score is an independent factor for predicting outcomes among patients with traumatic brain injury. At the cutoff score of 4, the Rotterdam system can predict outcomes among patients suffering from traumatic brain injury with acceptable sensitivity and specificity.**

## INTRODUCTION

Traumatic brain injury (TBI) is among the leading causes of death in the United States.[1] TBI is accountable for about 40% of all deaths induced by acute injuries in the United States and leads to about 52,000 deaths each year. Motor vehicle accidents (50%) and falls (20%–30%) are the most prevalent causes of TBI.[2]

The early diagnosis of TBI is critically important to make sound clinical decisions and to determine prognosis. One of the methods for such purposes is the Glasgow Coma Scale (GCS), which categorizes TBIs into mild, moderate, and severe according to the patient's level of consciousness. Use of the GCS at the time of hospital admission, however, is difficult and does not provide conclusive results because patients are intubated and/or receive narcotics. Moreover, GCS cannot differentiate among different types of intracranial injuries.[3] Another diagnostic technique for assessing TBI is brain imaging by computed tomography (CT) and magnetic resonance imaging (MRI). Brain imaging significantly helps the early diagnosis and the effective treatment of life-threatening conditions in patients with TBI.[4]

Brain CT is the gold standard for assessing patients with acute TBI. Given its ability to immediately show cranial and intracranial abnormalities, CT is considered as the modality of choice for evaluating patients with acute TBI. Moreover, it is used for

**Key words**
- Computed tomography
- Head trauma
- Rotterdam scoring system

**Abbreviations and Acronyms**
**CT**: Computed tomography
**GCS**: Glasgow Coma Scale
**MCS**: Marshall Classification System
**MRI**: Magnetic resonance imaging
**ROC**: Receiver operating characteristic
**RSS**: Rotterdam Scoring System
**TBI**: Traumatic brain injury

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determining the severity of brain injuries. MRI, however, also is used widely for brain imaging. Compared with CT, MRI has greater sensitivity for detecting contusions and diffuse axonal injuries.[5] It is associated, however, with several shortcomings, such as the inability to show skull fractures, subarachnoid hemorrhages, and hyper-acute hemorrhages, as well as a longer duration of imaging procedure. Consequently, MRI is mainly used for studying subacute and chronic TBIs.[6]

Integrating clinical examination findings with CT findings has significantly improved the ability to determine the prognosis of TBI. Performing clinical examinations on patients with TBI, however, is difficult. In addition, the accuracy of clinical examination findings greatly depends on the examiner's proficiency. Consequently, predictive models that are based solely on the findings of imaging studies, particularly CT, have been developed for resolving the shortcoming of clinical examination in this patient population.

Currently, there are 2 CT-based systems for evaluating CT findings, the Marshall Classification System (MCS) and the Rotterdam Scoring System (RSS).[7,8] The MCS, developed by Marshall et al.[7] in 1991, was the first CT-based system for determining the prognosis of TBI. The MCS classifies CT findings into 4 grades: Grade 1, no pathologic findings; Grade 2, basal cisterns are present and midline shift is less than 5 mm; Grade 3, basal cisterns are compressed; and Grade 4, midline shift is greater than 5 mm.[7] This system was developed primarily for predicting patient outcomes and the risk for increased intracranial pressure in patients with severe TBI. Despite its great use and applicability, the MCS has several limitations, such as failing to assess epidural hematomas and intracranial hemorrhages as well as having weak prognostic power for determining the prognosis of intracranial mass lesions.[9]

To overcome these shortcomings, in 2005 Maas et al.[8] introduced the RSS. This system provides a better estimation of disease prognosis by using certain criteria such as basal cisterns condition, midline shift, traumatic subarachnoid or intraventricular hemorrhage, and the epidural hematoma. Rotterdam scores predict posttrauma 6-month mortality rate as follows: score 1, 5%; score 2, 7%; score 3, 16%; score 4, 26%; score 5, 53%; and score 6, 61%.[8] Although it is not a fully validated scoring system and hence, further studies are still needed for its validation, the RSS has overcome some of the shortcoming of the MCS.[10]

The MCS and the RSS have been used and evaluated in several studies. For instance, Maas et al.[11] conducted a study to evaluate the correlation of CT findings with 6-month patient outcomes and found that CT-based classification was significantly correlated with outcomes of patients suffering from TBI. The worst outcomes were among patients with class III (brain edema) and IV (midline shift). Finally, they concluded that both independent and combined CT findings are significant predictors of outcomes in patients with TBI.[11] The results of another study, conducted by Mata-Mbemba et al.[9] on 245 patients with mild-to-severe TBIs, also revealed that the predictive power of the MCS and the RSS were almost the same. Other studies also have shown that the RSS scores are significantly correlated with death and other adverse outcomes among patients with TBI[3,12,13]; however, Washington and Grubb[14] conducted a retrospective study on 1101 patients with TBI and found a weak relationship between death and Rotterdam score.

Most of the previous studies that used the RSS for outcome prediction dealt mainly with long-term patient outcomes. Moreover, the results of the previous studies in this area are conflicting. In addition, to the best of our knowledge, the RSS has not been used and evaluated in our country, Iran. This study was conducted to narrow these gaps. The aim of the study was to determine the prognostic value of the RSS to predict early death among patients with TBI.

## PATIENTS AND METHODS

This prospective study was conducted in 2014. Official approval was obtained for this study from the Ethics Committee of Kashan University of Medical Sciences, Kashan, Iran. Written informed consent for participation in the study also was obtained from all the participating patients. Eligible patients were recruited by using the nonrandom sampling method from the Emergency Department of Shahid Beheshti teaching hospital, Kashan, Iran. Patients were included if they were older than 15 years of age, had abnormal findings on CT or a GCS score of less than 14, and no accompanying lesions (such as brain tumor, hydrocephalus, etc.). Patients who died during the study as the result of causes other than TBI or patients who could not be monitored during the follow-up period were excluded.

### Sample Size

Study sample size was calculated by use of the findings of a study conducted by Maas et al.[8] They reported that the likelihood of death among patients with a Rotterdam score of 4 or greater was equal to 26%. Consequently, with a confidence interval of 0.95, it was determined that a sample of 150 patients was needed.

### Measurements

The study instrument was a checklist including items on patients' demographic characteristics, such as sex and age as well as trauma-related data, such as the mechanism of trauma, GCS score, CT findings based on the RSS, and early 14-day outcomes of either recovery or death.

Patients who were hospitalized in the study setting initially received primary care measures, and their GCS score was determined by an emergency physician. Then, a CT was performed for each of them with a Toshiba Asteion CT scanner (Tokyo, Japan). CT images were obtained from the skull base in (5-mm thickness) and brain parenchyma up to vertex in (10-mm thickness). All CT images were interpreted separately by a radiologist and a neurosurgeon who were blinded to the clinical conditions of patients, including GCS, patient treatments, and outcome. Their agreement about each criterion of Rotterdam score was assessed in a pilot study on 10 patients with acceptable kappa coefficient. In cases of interobserver disagreement, CT images were interpreted by another radiologist, and scoring was completed on the basis of that observer's opinion. Rotterdam scores were determined on the basis of the 4 criteria of condition of the basal cisterns, midline shift, epidural mass lesions, and intraventricular or subarachnoid hemorrhage. The scoring of each of these 4 criteria was as follows:

- basal cisterns condition: normal: 0; compressed: 1; absent: 2;
- midline shift: No shift or a shift of <5 mm: 0; A shift of >5 mm: 1;
- epidural hematoma: absent: 0; present: 1; and
- intraventricular or subarachnoid hemorrhage: absent: 0; present: 1

The sum of the scores of these 4 criteria plus 1 was considered as the final score of the RSS.[3] Consequently, the minimum and the maximum possible scores were 1 and 6, respectively.

All patients were managed by standard protocols for TBI, including proper brain tissue perfusion and oxygenation. All of the patients with GCS <13 were admitted to intensive care unit for close monitoring. On the basis of the patient's condition and the neurosurgeon's decision, medical or surgical treatments were delivered. The patients were monitored for 14 days regarding the early outcomes of either recovery, death, or no significant changes in medical condition. In case of death, a neurosurgeon determined the cause of death. If the death had happened secondary to causes other than TBI, the patient was excluded from the study.

### Analysis

Data analysis was performed with the SPSS v. 16 (IBM, Armonk, New York, USA). The relationship of Rotterdam score with other study variables was examined by conducting univariate analyses whereas the relationship of this score with patient outcomes was assessed with the logistic regression technique and calculating odds ratios. Moreover, we did receiver operating characteristic (ROC) analysis and calculated sensitivity and specificity parameters for determining the best cutoff score of the RSS. All P values which were less than 0.05 were considered as significant.

**Table 1.** The Relationship of Demographic Characteristics with Patient Outcomes

| | Outcome | | | |
|---|---|---|---|---|
| Variable | Alive *n* (%) | Death *n* (%) | Total *n* (%) | *P* Value |
| Sex | | | | 0.75 |
| Male | 24 (85.7) | 4 (14.3) | 28 (100) | |
| Female | 107 (87.7) | 15 (12.3) | 122 (100) | |
| Age, years | | | | 0.03 |
| <19 | 27 (93.1) | 2 (6.9) | 29 (100) | |
| 20–39 | 64 (88.9) | 8 (11.1) | 72 (100) | |
| 40–59 | 27 (90) | 3 (10) | 30 (100) | |
| >60 | 13 (68.4) | 6 (31.6) | 19 (100) | |
| GCS | | | | 0.001 |
| Mild (13–15) | 109 (100) | 0 (0) | 109 (100) | |
| Moderate (9–12) | 20 (76.9) | 6 (23.1) | 26 (100) | |
| Severe (3–8) | 2 (13.3) | 13 (86.7) | 15 (100) | |
| Mechanism of trauma | | | | 0.6 |
| Traffic accident | 124 (87.9) | 17 (12.1) | 141 (100) | |
| Fall | 7 (77.8) | 2 (22.2) | 9 (100) | |
| Other organ injury | | | | 0.48 |
| No | 93 (88.6) | 12 (11.4) | 105 (100) | |
| Yes | 38 (84.4) | 7 (15.6) | 45 (100) | |

GCS, Glasgow Coma Scale.

## RESULTS

In this study 162 patients were recruited. Twelve patients died as the result of intra-abdominal organ injury and were excluded from the study. Because of the short follow-up time, we did not have any loss to follow-up. Participants were mostly male (81.3%) with a mean age of 34.2 ± 18.7 years. Four female and 15 male patients (19 in total; 12.7%) died during the 14-day follow-up period; however, the difference between male and female patients regarding rate of death was not statistically significant. The highest and the lowest death rate values were related to the age groups of older than 60 years (31.6%) and younger than 19 years (6.9%), respectively. The means of age for the dead and the surviving patients differed significantly. Most of the patients who experienced death suffered from moderate-to-severe TBIs. The severity of TBI was significantly correlated with patient outcomes ($P < 0.001$). However, the relationship of patient outcomes with the mechanism of trauma and injury of other organs was not statistically significant (Table 1).

The Rotterdam score of 50% of the patients was equal to 2. Moreover, all patients who survived had a Rotterdam score of 4 or less. There was a significant correlation between Rotterdam score and patient outcomes ($P < 0.001$). We cross-tabulated patient outcomes with the 4 criteria of the RSS and found that 75% of patients with absent basal cisterns, 83.3% of patients with midline shift, 9.6% of patients with epidural lesions, and 42.9% of patients with intra ventricular hemorrhage died. Patient outcome was significantly correlated with all 4 criteria of the RSS. Figure 1 shows the direct relationship of the Rotterdam score with the rate of death among patients with TBI.

The cutoff score of the RSS was calculated by using the ROC curve. At the cutoff score of 3, the sensitivity and the specificity of

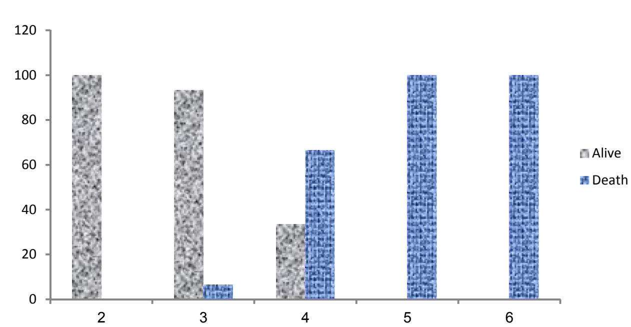


**Figure 1.** Rotterdam score and patient outcomes.

the RSS were 100% and 62.6%, respectively; however, at the cutoff score of 4, these parameters were respectively equal to 84.2% and 96.2%. Accordingly, the sensitivity and the specificity of the system were more acceptable at the cutoff score of 4 (Table 2). Figure 2 shows the area under the ROC curve.

The rate of death among patients with Rotterdam scores of 4 or greater and less than 4 was equal to 84.2% and 3.8%, respectively. The odds ratio for the relationship of Rotterdam score and patient outcomes was 134.4 (95% confidence interval 29.3–616.3; $P < 0.001$). The results of logistic regression analyses revealed that factors such as age, sex, GCS score, and Rotterdam score significantly contributed to patient outcomes ($P < 0.05$; Table 3). The greatest odds ratio value was related to Rotterdam score (adjusted odds ratio = 125.2).

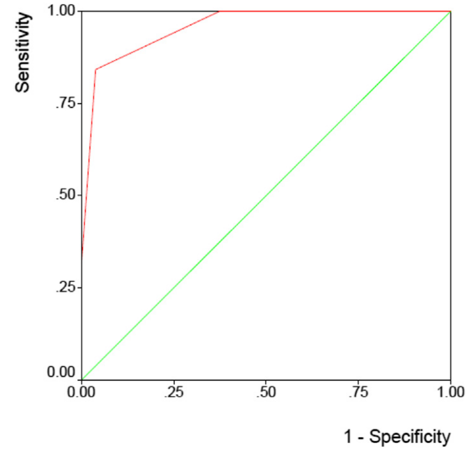


**Figure 2.** The receiver operating characteristic curve for determining the sensitivity and the specificity of the Rotterdam Scoring System.

## DISCUSSION

In this study, we determined the prognostic value of the RSS to predict early death among patients with TBI. Study findings revealed that at the cutoff score of 4, the sensitivity and the specificity of the RSS for predicting the mortality during 14 days were 84.2% and 96.2%, respectively. Leitgeb et al.[12,13] also found a significant correlation between Rotterdam score and rate of mortality among patients with moderate-to-severe TBIs. The findings of another study conducted by Huang et al.[3] on 127 patients who had undergone post-TBI craniotomy also revealed that the RSS was an independent predictor of death and other negative outcomes; however, Washington and Grubb[14] found a weak correlation between death and Rotterdam score. The reason behind this conflict can be the differences in the types and the samples of the studies. Washington and Grubb conducted a retrospective study on patients with mild TBI, whereas our study was performed prospectively on patients with mild-to-severe TBIs.

We also found that the 4 criteria of the RSS (i.e., absent basal cisterns, midline shift, epidural lesions, and intraventricular or subarachnoid hemorrhage) could independently predict patient outcomes. To our knowledge, only Mata-Mbemba et al.[9] evaluated the relationship of patient outcomes with these 4 criteria. They reported that absent basal cisterns and midline shift had the strongest correlation with death.

The mortality rate in our study was equal to 12.7%. Mata-Mbemba et al.[9] also conducted a study in Japan and reported a predischarge mortality of 10.2%; however, Huang et al.[3] reported a mortality rate of 32.3%. These conflicting results can be linked to the fact that Huang et al.[3] conducted their study on patients undergoing post-TBI craniotomy by using a retrospective design. Moreover, they monitored patients for 6 months. Leitgeb et al.[12,13] also reported a mortality rate of 46.7% and 30.8% for patients with severe subdural and epidural hematomas, respectively. These mortality rates were much greater than the value found in our study. The reason behind this difference is probably the differences in the types and the severity of traumas.

Study findings also revealed that 3.8% of patients with a Rotterdam score of less than 4 experienced early death, whereas this value among patients with a Rotterdam score of 4 or greater was as high as 84.2%. In the study conducted by Huang et al.,[3] these values were equal to 2.5% and 97.5%, respectively. This discrepancy between the findings of the 2 studies may be attributable to the types of provided health care services, the designs and the samples of the studies, and the length of follow-up period.

We also found that factors such as age, sex, initial GCS score, and Rotterdam score were related to TBI prognosis. The strongest effect was related to Rotterdam score. This finding is in line with the findings of the previous studies. For instance, Signorini et al.[15]

**Table 2.** The Best Cutoff Scores of the RSS for Predicting Outcomes in Patients with TBI

| Factor | Cut Point | Sensitivity | Specificity | AUC |
|---|---|---|---|---|
| Rotterdam Score | 3 | 100 | 62.6 | 0.975 |
| | 4 | 84.2 | 96.2 | |

RSS, Rotterdam Scoring System; TBI, traumatic brain injury; AUC, area under the curve.

**Table 3.** The Logistic Regression Model for the Predictor of Early Death Among Patients with TBI

| Factor | B | SE | Significance | Odds Ratio |
|---|---|---|---|---|
| Age | −0.06 | 0.02 | 0.004 | 0.94 |
| Sex (Female/Male) | 3.79 | 0.89 | <0.001 | 44.2 |
| GCS | 1.23 | 0.61 | 0.04 | 3.44 |
| Rotterdam score | 4.83 | 1.0 | <0.001 | 125.19 |
| Other organ Injury | −1.02 | 0.85 | 0.23 | 0.36 |

TBI, traumatic brain injury; SE, standard error; GCS, Glasgow Coma Scale.

conducted a study on 372 patients with moderate-to-severe TBIs and reported age, initial GCS score, injury severity score, pupil reaction to light, and presence of hematoma as the independent predictors of patient outcomes. Pillai et al.[16] also assessed 289 patients with extensive, severe TBIs and GCS scores of less than 8 and reported that factors such as age, the mechanism of trauma, initial GCS score, pupil reaction to light, horizontal oculocephalic reflex, and CT findings predicted the 3 outcomes of death, stable vegetative state, and disability with a sensitivity and a specificity of respectively 67% and 75%.[16] The studies conducted by Leitgeb et al.[12,13] also revealed age and TBI severity as the main predictors of patient outcomes.

One of the strengths of the study was that it evaluated the predictive value of the RSS among patients with all degrees of TBI, whereas previous studies had mainly assessed patients with moderate-to-severe TBIs. Moreover, the present study was conducted prospectively, whereas previous studies were mostly retrospective. One limitation of the study was that we only assessed patient outcomes that occurred during the first 2 weeks after hospital discharge. Consequently, we recommend assessing the prognostic value of the RSS to predict long-term outcomes such as TBI-induced disability and death. Moreover, it is recommended to conduct studies to compare the prognostic value of the MCS and the RSS for predicting outcomes after mild-to-severe TBIs.

## CONCLUSIONS

The findings of the present study indicate that at the cutoff score of 4, Rotterdam score can predict post-TBI patient outcomes with acceptable sensitivity and specificity. Moreover, the RSS can be used as an independent factor for predicting post-TBI outcomes. Given its simplicity, applicability, and objectivity, we recommend using the RSS for the initial assessment of patients with TBI.

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