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The Use of Rotterdam CT Score for Prediction of Outcomes in Pediatric Traumatic Brain Injury Patients Admitted to Emergency Service

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Keywords

Pediatric traumatic brain injuries · Rotterdam CT score · Glasgow coma scale

Abstract

Introduction: Rotterdam CT score for prediction of outcome in traumatic brain injury is widely used for patient evaluation. The data on the assessment of pediatric traumatic brain injury patients with the Rotterdam scale in our country are still limited. In this study, we aimed to evaluate the use of the Rotterdam scale on pediatric trauma patients in our country and assess its relationship with lesion type, location and severity, trauma type, and need for surgery. ***Methods:*** A total of 229 pediatric patients admitted to the emergency service due to head trauma were included in our study. Patients were evaluated in terms of age, gender, Glasgow Coma Scale (GCS), initial and follow-up Rotterdam scale scores, length of stay, presence of other traumas, seizures, antiepileptic drug use, need for surgical necessity, and final outcome. ***Results:*** A total of 229 patients were included in the study, and the mean age of the patients was 95.8 months. Of the patients, 87 (38%) were girls and 142 (62%) were boys. Regarding GCS at the time of admission, 59% (n = 135) of the patients had mild (GCS = 13–15), 30.6% (n = 70) had moderate (GCS = 9–12), and 10.5% (n = 24) had severe (GCS < 9) head trauma. The mean Rotterdam scale score was calculated as 1.51 (ranging from 1 to 3) for mild, 2.22 (ranging from 1 to 4) for moderate, and 4.33 (ranging from 2 to 6) for severe head trauma patients. Rotterdam scale score increases significantly as the degree of head injury increases ($p < 0.001$). ***Discussion:*** With the adequate use of GCS and cerebral computed tomography imaging, pediatric patients with a higher risk of mortality and need for surgery can be predicted. We recommend the follow-up of pediatric traumatic brain injury patients with repeated CT scans to observe alterations in Rotterdam CT scores, which may be predictive for the need for surgery and intensive care.

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Introduction

Rotterdam CT score for prediction of outcome in traumatic brain injury was defined by Maas et al. [1] and widely used for patient evaluation in acute settings. Rotterdam score is primarily based on the morphology of basal cisterns, presence of midline shift, epidural mass lesion, and intraventricular blood or traumatic subarachnoid hemorrhage. If the patient's basal cisterns are compressed or completely disappeared in the CT image, the patient receives 1 or 2 points, respectively. A midline shift >5 mm, absence of epidural mass lesion, and presence of intraventricular blood or traumatic subarachnoid hemorrhage add 1 point to the scale [1]. The patients may receive a Rotterdam CT score ranging from 0 to 6, where the mortality risk increases with increasing score points [2] (Table 1).

Rotterdam CT score was developed in adults; however, it can be utilized in pediatric patients as well. According to a study by Liesemer et al. [2], Rotterdam CT score had an AUC value of 0.85 with a 95% confidence interval ranging from 0.80 to 0.89 in pediatric patients. Nevertheless, the authors stated that this model has poor calibration and may lead to over- or underestimations in the prediction of pediatric mortality. A predictive model on children with moderate-to-severe trauma showed better calibration and fit for prediction of mortality in pediatric traumatic brain injury patients with an AUC of 0.80 (95% CI: 0.68–0.91) [2]. Another study on pediatric patients with traumatic brain injury in intensive care settings showed that Rotterdam CT score performed inferior to Helsinki CT score, with AUC values of 0.80 (95% CI: 0.73–0.86) and 0.84 (95% CI: 0.78–0.90), respectively. The pseudo R2 values of Helsinki and Rotterdam scales were 0.39 and 0.34, respectively [3]. Another study showed that the Rotterdam score is significantly associated with mortality and recovery in pediatric patients [4]. However, further studies are needed to increase data on the use of Rotterdam CT score on pediatric patients admitted to emergency services with traumatic brain injury.

The data on the evaluation of pediatric traumatic brain injury patients with the Rotterdam scale in our country are still limited. The use of the Rotterdam scale in pediatric patients with head trauma is vital to predict the prognosis of this patient group, and better prognostic stratification may lead to saving lives in emergency settings. In this study, we aimed to evaluate the use of the Rotterdam scale on pediatric trauma patients in our country and assess its relationship with lesion type, location and severity, trauma type, and need for surgery.

Table 1. Rotterdam CT scale

Predictor value	Score
Basal cisterns	
Normal	0
Compressed	1
Absent	2
Midline shift	
No shift or shift ≤5 mm	0
Shift >5 mm	1
Epidural mass lesion	
Present	0
Absent	1
Intraventricular blood or tSAH	
Absent	0
Present	1
Sum score[a]	+1

tSAH, traumatic subarachnoid hemorrhage. [a] The sum score can be used to obtain the predicted probability of mortality from the below formula. We chose to add plus 1 to make the grading numerically consistent with the grading of the motor score of the GCS. Probability (mortality) = $1 / (1 + e^{-(-2.6 + 0.8 \times \text{sumscore})})$.

Materials and Methods

A total of 229 pediatric patients admitted to the emergency service of our hospital due to head trauma between January 2017 and September 2019 were included in our study. Patients were evaluated in terms of age, gender, Glasgow Coma Scale (GCS), initial and follow-up Rotterdam scale scores, length of stay, presence of other traumas, seizures, antiepileptic drug use, need for surgical necessity, and final outcome.

The patients aged 0–216 months with cerebral computed tomography (CCT) images obtained in admissions were included in this study. The patients without accessible information, evaluable imaging, or patients with cranial pathologies other than trauma (e.g., tumor, hydrocephaly) were excluded from the study. The data were obtained from the hospital database (Hospital Information Management System) and patient files, and images were accessed from the hospital image archive system (PACS), and these images were individually scanned and evaluated by 2 researchers. Rotterdam scale is a prognostic scale, which is used to predict mortality in head trauma, where basal cisterns, midline shift, occupying lesions in epidural space, and presence of intraventricular hemorrhage or subarachnoid hemorrhage in CT scan were evaluated [1].

Statistical Analysis

Bivariate correlation tests (Pearson's R and Spearman's tests) were used to assess the correlation between the variables. Mann-Whitney U test was used in the analysis of variables that did not fit the normal distribution. A χ^2 test was performed for categorical data. SPSS software for Windows (version 20.0) was used for analysis. A p value of <0.05 was considered significant. Ethical ap-

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Table 2. Glasgow Coma Scale (GCS) and Rotterdam CT scores according to the pathology in imaging

Pathology	Rate, %	GCS			Rotterdam (mean ± SD)
		mild, %	moderate, %	severe, %	
Epidural hematoma	23.6	10.9	11.8	0.9	1.98±0.73
Linear fracture	16.6	14.4	1.7	0.4	1.42±0.92
Subarachnoid hemorrhage	12.2	4.4	6.1	1.7	3.25±1.08
Subdural hematoma	7.4	3.1	2.6	1.7	2.47±0.87
Pneumocephalus	7.4	4.8	2.6	0.0	1.59±0.50
Depression fracture	5.7	3.9	1.7	0.0	1.77±0.60
Contusion	5.2	3.5	1.3	0.4	1.58±0.90
Intracerebral/intraventricular hemorrhage	3.9	0.0	1.7	22.0	3.56±1.74
Edema	3.1	0.0	0.4	2.6	4.14±1.68
Normal	14.8	14.0	0.4	0.4	1.17±0.39
			$p < 0.001$		**$p < 0.001$**
Rotterdam scale (mean)		1.51	2.22	4.33	

GCS, Glasgow Coma Scale.

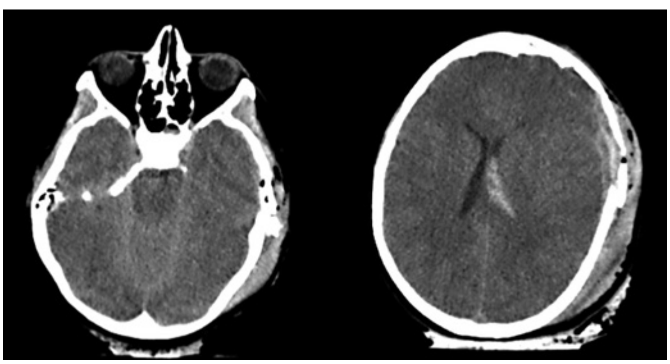

Fig. 1. Ten-year-old male patient. It is seen that basal cisterns are disappeared, and intraventricular hematoma, 5-mm midline shift, edema, and fracture are seen in cranial CT. The patient was evaluated as 6 points according to the Rotterdam scale and died on the 24th day of the follow-up.

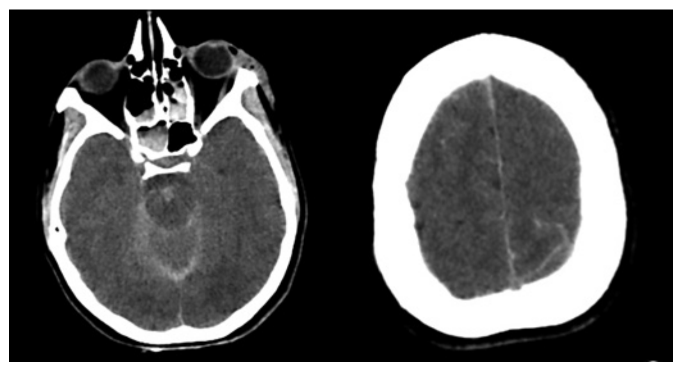

Fig. 2. Fourteen-year-old female patient. It is seen that the basal cisterns are disappeared, and SAH at the vertex level is seen in cranial CT. The patient was evaluated as 5 points according to the Rotterdam scale and died on the 10th day of follow-up.

proval for this study was obtained from the Ethics Committee of our hospital on January 19, 2019 with protocol number 258, and the research has complied with the Declaration of Helsinki principles.

Results

A total of 229 patients were included in the study. Of the patients, the youngest was 15 days old and the oldest was 216 months old, and the average age was 95.8 months. Of the patients, 87 (38%) were girls and 142 (62%) were boys.

Regarding GCS at the time of admission, 59% ($n = 135$) of the patients had mild (GCS = 13–15), 30.6% ($n = 70$) had moderate (GCS = 9–12), and 10.5% ($n = 24$) had severe head trauma. When the primary pathologies of the patients were evaluated, it was observed that 23.6% of the patients ($n = 54$) had epidural hematoma, 16.6% ($n = 38$) linear fracture, 12.2% ($n = 28$) subarachnoid hemorrhage, 7.4% ($n = 17$) subdural hematoma, 7.4% ($n = 17$) subdural hematoma pneumocephalus, 5.7% ($n = 13$) depressed fracture, 5.2% ($n = 12$) contusion, 3.9% ($n = 9$) intracerebral/intraventricular hemorrhage, and 3.1% ($n = 7$) had edema. No pathology was detected in cranial imaging of 34 patients (14.8%) (Table 2; Fig. 1–4).

Table 3. GCS and Rotterdam CT scores according to the localization of pathology

Pathology	Rate, %	GCS			Rotterdam (mean ± SD)
		mild, %	moderate, %	severe, %	
Diffuse	4.8	0.5	0.5	4.6	4.3±1.91
Multiple	11.8	0.5	3.6	1.0	2.8±0.79
Temporal	30.0	8.2	5.7	0.0	1.8±0.77
Parietal	10.9	11.9	10.8	2.0	2.1±1.03
Occipital	30.1	11.3	1.5	0.0	1.5±0.50
Frontal	1.7	19.6	12.9	3.1	2.0±1.02
Intraventricular	84.7	1.0	0.0	1.0	3.3±1.25
Rotterdam scale (mean± SD)			***p* < 0.001**		***p* < 0.001**

GCS, Glasgow Coma Scale.

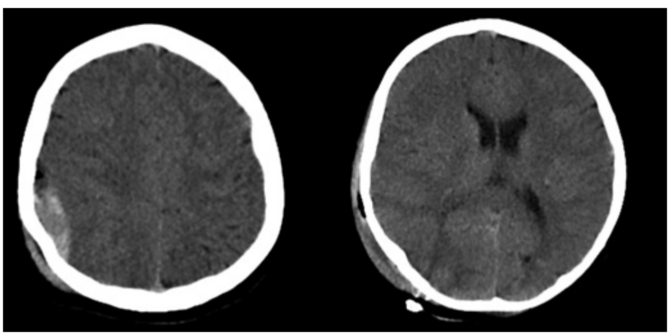

Fig. 3. Eleven-year-old male patient. Minimal displacement fracture is observed with EDH in the right parietal region. The patient got 1 point according to the Rotterdam scale and was discharged with full recovery.

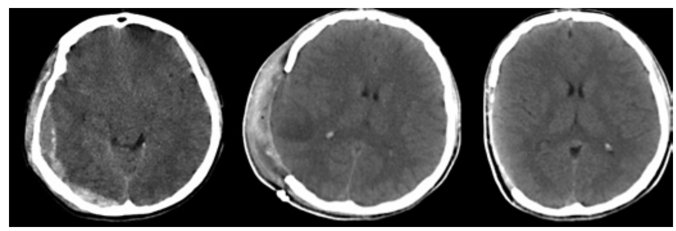

Fig. 4. Fifteen-year-old female patient. Right parieto-temporo-occipital subdural hematoma, mild wiping in the basal cisterns, and midline shift are observed in the cranial CT. She received 3 points according to the Rotterdam scale, and the patient underwent decompressive craniectomy and hematoma drainage. Early and late postoperative CT are given. The patient was discharged and transferred to rehabilitation.

According to the location of the lesion, 35.6% ($n = 69$) of the patients had frontal, 24.7% ($n = 48$) parietal, 13.9% ($n = 27$) temporal, 12.9% ($n = 25$) occipital, 2.1% ($n = 4$) intraventricular, and 5.7% ($n= 11$) widespread lesions, and 5.2% ($n = 10$) of the patients had lesions in multiple regions (patients without any pathology detected in cranial imaging are not included) (Table 3).

When the Rotterdam scale was analyzed, it was found that the patients had an average of 2.03, where the evaluation was made over 1–6 points. In the follow-up imaging, the patients' mean Rotterdam scale score was calculated as 3.10. Of the patients, 17.9% ($n = 41$) were multi-trauma patients, and 28.4% ($n = 65$) of patients were followed up in the intensive care unit and 71.6% (164) were followed in the clinics or emergency department. Antiepileptic treatment was initiated in 28.4% ($n = 65$) of patients, and 9.6% ($n = 22$) of patients had seizure history. Of the patients, 10.5% ($n = 24$) needed surgery and the mortality rate was found as 5.7% ($n = 13$).

Considering the diagnosis of patients and GCS, linear fracture, pneumocephalus, depressed fracture, and contusion in mild head trauma; subarachnoid hemorrhage and epidural hematoma in moderate head trauma; and intracerebral/intraventricular hemorrhage, subdural hematoma, and edema in severe head trauma, were significantly higher ($p < 0.001$). In mild head trauma, the lesion in 1 region (frontal, temporal, parietal, or occipital); in moderate head injury, lesions in multiple sites, and in severe head trauma, diffuse or intraventricular lesions were significantly higher ($p < 0.001$) (Tables 2, 3).

Multi-trauma was detected in 9.6% of patients with mild head trauma, 15.7% of patients with moderate head trauma, 70.8% of patients with severe head trauma, and the differences were found significant ($p < 0.001$). Seizures were developed in 0.7% of patients with mild head trauma, 7.1% of patients with moderate head trauma, 66.7% of patients with severe head trauma, and the differences among the groups were statistically significant (p <

0.001). There was a need for surgery in 1.5% of patients with mild head trauma, 24.3% of patients with moderate head trauma, and 20.3% of patients with severe head trauma. All cases resulting in mortality were patients with severe head trauma. The mean Rotterdam score in girls was found as 2.06, compared to 2.00 in boys. The mean Rotterdam scale score was calculated as 1.51 (ranging from 1 to 3) in mild head trauma, 2.22 (ranging from 1 to 4) in moderate head trauma, and 4.33 (ranging from 2 to 6) in severe head trauma. Rotterdam scale score increases significantly as the degree of head injury increases ($p < 0.001$)

When mean Rotterdam scale scores of lesion types were compared, it was observed that cases with cerebral edema had a score of 4.13, intracerebral hematoma 3.55, subarachnoid hemorrhage 3.25, subdural hematoma 2.47, epidural hematoma 1.98, depressed fracture 1.76, pneumocephalus 1.58, contusion 1.58, and linear fracture 1.42, and differences among the groups were statistically significant ($p < 0.001$). Regarding lesion localization, the mean Rotterdam score was calculated as 4.36 for cases with brain edema, 3.25 for intraventricular pathology, 2.80 for pathologies with multiple of affected areas, 2.04 for the parietal and frontal region lesions, 1.85 for temporal region lesions, and 1.52 for occipital lesions, and differences between the groups were statistically significant ($p < 0.001$) (Table 2; Fig. 1–4)

The mean Rotterdam scale score of patients with multi-trauma was 2.87, while the mean Rotterdam scale score in patients with isolated head trauma was calculated as 1.84. Furthermore, the mean Rotterdam scale score of the patients who were followed up in the clinic or emergency department was found as 1.68; however, the average Rotterdam scale score of the patients followed up in the intensive care unit was 2.87. Besides, the mean Rotterdam scale score of patients with a history of seizures was 3.95, whereas the average Rotterdam scale score of patients without seizures was 1.82. The mean Rotterdam scale score of patients in whom antiepileptic drugs were started was 3.21, though the mean Rotterdam scale score of those without antiepileptic drug use was found as 1.54. The mean Rotterdam scale score of cases resulted in mortality was 5.07, in comparison to the mean Rotterdam scale score of those who were discharged after treatment or discharged with healing was 1.84. All differences in the abovementioned comparison were statistically significant. ($p < 0.001$). While the mean Rotterdam scale score of patients with surgical need was calculated as 2.79, the mean Rotterdam scale score of patients without surgical necessity was 1.93, and the difference was found statistically significant ($p < 0.001$).

An increase of 1–3 points in the Rotterdam scale of the follow-up (or control) CCT was observed in a total of 20 patients. Of these patients, 80% were boys, and the mean Rotterdam scale score in the control CCT was found as 3.25. The mean Rotterdam scale score in the control CCT for girls was 2.50. The difference between 2 groups was statistically not significant ($p = 0.380$).

The mean Rotterdam scale score in control CCT was increased in 4 (2.96%) of mild head trauma patients, 11 (15.7%) of moderate head trauma patients, and 5 (20.8%) of severe head trauma patients compared to baseline Rotterdam scale score. An increased mean Rotterdam scale score in control CCT was detected in patients with epidural hematoma (50%, $n = 10$), subdural hematoma (20%, $n = 4$), and subarachnoid hemorrhage (15%, $n = 3$), most frequently. An increase in the mean Rotterdam scale score was observed in 1 patient with pneumocephalus, linear fracture ($n = 1$), and intracerebral hematoma ($n = 1$). Considering the localization of lesions, 9 patients (45%) with frontal lesions, 5 patients (25%) with parietal lesions, and 4 patients (40%) with temporal lesions, and in all of 2 patients with lesions with multiple localizations, an increase in Rotterdam scores in control CCT was found. However, the difference was statistically not significant ($p > 0.05$).

Regarding control CCT, 60% of patients whose mean Rotterdam scale score was increased were intensive care patients, and this difference was statistically significant ($p = 0.012$). Of the patients, 95% were patients who were naturally discharged or discharged with healing ($p = 0.041$). Surgery was required in 50% of patients, and this was considered statistically significant ($p = 0.031$).

Discussion/Conclusion

In this study, we intended to analyze the use of the Rotterdam scale on pediatric trauma patients in our country and assess its relationship with lesion type, location and severity, trauma type, and need for surgery. According to our results, the most frequent head trauma lesion was in the frontal region. Previous literature shows similar results for traumatic extradural hematoma and traumatic brain injuries with a contusion [5, 6]. We found the mean Rotterdam scale score of our patients as 2.03, where this score showed significant differences among mild, moderate, and severe traumatic brain injuries. Similarly, Atike Ongun et al. [4] found that the mean Rotterdam scores were increasing as the severity of head trauma increased. They reported Rotterdam scores of 1.74 ± 0.77, 2.0 ± 0.53, and 3.83 ± 1.48, for mild, moderate, and severe traumatic brain injury groups, respectively [4]. We have found that patients with severe traumatic brain injury were more likely to be multi-trauma patients. Previously, Crawford et al. [7] demonstrated that concomitant blunt chest trauma was related to higher morbidity and mortality in traumatic brain injury patients.

According to our results, patients with severe traumatic brain injury were more prone to have seizures. Likewise, the results of the study by Parmontree et al. [8] showed the relationship between the severity of traumatic brain injuries and early seizures. The same study showed that the diffuse injury classes of V and VI, according to the Marshall CT classification, were more likely to have early seizures after traumatic brain injury, which is comparable with our results on the significantly higher Rotterdam scores of patients with a seizure history [8]. Huang et al. [9] found that for head-injured patients undergoing decompression surgery, the Rotterdam CT score provides great prognostic discrimination and is an independent predictor of unfavorable outcomes. We found that patients with severe traumatic brain injury had higher rates of need for surgery. Previously, Talari et al. [10] showed that the patients with the need for surgery had higher mortality compared to the patients without the need for surgery. The cure rate for both medical and surgical treatment decreases with the increasing Rotterdam score [10]. Likewise, we found that the patients with a need for surgery had higher Rotterdam scores and severity of traumatic brain injury.

We could not find any significant differences between 2 genders in terms of initial Rotterdam scores and rise in follow-up (control) Rotterdam score. However, Miles et al. [11] have found that female gender was associated with a higher risk of intracranial hypertension in pediatric patients. We have found that traumatic brain injury patients with brain edema had the highest Rotterdam scores, followed by the patients with intracerebral hematoma and subarachnoid bleeding. Similarly, Das et al. [12] demonstrated that the Rotterdam score is correlated with optic nerve sheath diameter, which is associated with diffuse cerebral edema and subdural and extradural hematoma. Waqasa et al. [13] analyzed the Rotterdam CT scores and optic nerve sheath diameter as predictors of outcome in patients requiring decompressive craniectomy. Optic nerve sheath diameter as a predictor of mortality was not significantly different between survivors and non-survivors. Rotterdam scale was a significant predictor of 30-day mortality; thus, they inferred that high values of admission. Optic nerve sheath diameter does not predict mortality or unfavorable outcomes in decompressive craniectomy patients, as opposed to Rotterdam scale [13]. We demonstrated that the Rotterdam scale score was significantly higher in traumatic brain injury cases resulting with mortality, which has been documented well in the previous literature [14].

We have found that the patients with a need for surgery and intensive care unit patients had increased Rotterdam scores compared to Rotterdam scores of initial CCT. In a previous study on 88 pediatric patients with traumatic brain injury, who were followed up with repeated CT scans, Atike Ongun and Dursun [4] showed that prolonged intubation, intensive care, and staying in the hospital were associated with axonal injury.

GCS is not a scale that can be used effectively in children. Therefore, the prediction for clinical outcome is insufficient. At the same time, GCS, the examiner, the time of the examination and sedation and agitation of the patient are affected. Disadvantages of using CT imaging include lack of real-time measurements and difficulty obtaining repeated measurements, in terms of logistics, radiation exposure, and cost [12].

In this study, we demonstrated that the Rotterdam CT score as a valuable tool of prognostic stratification in emergency settings, where information obtained from the neurological examination is limited. With the adequate use of GCS and CCT imaging, pediatric patients with a higher risk of mortality and need for surgery can be predicted. We recommend the follow-up of pediatric traumatic brain injury patients with repeated CT scans to observe alterations in Rotterdam CT scores, which may be predictive for the need for surgery and intensive care.

Statement of Ethics

The study was approved by the Ethics Committee of our hospital. The study complied with the Declaration of Helsinki.

Conflict of Interest Statement

The authors have no conflicts of interest to declare.

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Author Contributions

Conception and design: S.K., P.A.O., M.O., S.A., S.E., S.C., and O.B. Acquisition, analysis, and interpretation of data: P.A.O., S.C., S.E., and O.B. Approved final version of the manuscript: S.K., P.A.O., M.O., and S.A.

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