Journal of Surgical Radiology

Site: https://journalsurgrad.com/

ISSN Print 2156-213X| ISSN Online: 2156-4566 Volume: 05 Issue: 06 Open Access

Research Article

Comparative Accuracy of Helsinki and Rotterdam CT Scores in Predicting Clinical Outcome in Patients with Blunt Traumatic Brain Injury: A Prospective Observational Study

Dr. Yashawanth Vivek B M[1], Dr. Vijay Kumar K R[1], Dr. Sirish Shivaramaiah[2]

[1]Department of Radiodiagnosis, Bangalore Medical College and Research Institute (BMCRI), Bengaluru, Karnataka, India.

[2]Department of Radiology, Bangalore Medical College and Research Institute (BMCRI), Bengaluru, Karnataka, India.

*Corresponding Author
Dr. Sirish Shivaramaiah,
Email: sirishs7@gmail.com.

Article History
Received: 10-05-2026
Revised: 25-05-2026
Accepted: 10-06-2026
Published: 23-06-2026

Citations:
Vivek BMY, Kumar KRV, Shivaramaiah S. Comparative accuracy of Helsinki and Rotterdam CT scores in predicting clinical outcome in patients with blunt traumatic brain injury: A prospective observational study. J Surg Radiol, V5 (6) 557-568

Abstract: ***Introduction:*** Traumatic brain injury (TBI) is a major global health burden, with over 50 million new cases annually and rising incidence. Clinical tools like the GCS have limited reliability, making CT-based scoring systems such as the Rotterdam and Helsinki scores important for objective prognostication. While both scores predict outcomes, comparative studies show mixed results—Rotterdam performs better for mortality while Helsinki shows higher sensitivity for 6-month functional outcome. This study compares the Helsinki and Rotterdam CT scores for predicting six-month outcome in blunt TBI patients in an Indian tertiary care setting. **Objective:** Early prognostication in traumatic brain injury (TBI) guides management, resource allocation and counselling. Computed tomography (CT)-based scoring systems refine risk stratification beyond clinical assessment, but prospective comparative data in blunt TBI remain limited. We compared the accuracy of the Helsinki and Rotterdam CT scores in predicting mortality and six-month clinical outcome in blunt TBI. **Methods:** This prospective observational study enrolled 106 adults with blunt TBI at a tertiary care trauma centre over 18 months. All patients underwent non-contrast CT brain at admission; scans were scored independently by two neuroradiologists using the Helsinki and Rotterdam systems, blinded to outcome. Outcome was assessed at six months using the Glasgow Outcome Scale–Extended (GOSE), dichotomised into favourable (GOSE 5–8) and unfavourable (GOSE 1–4). Analysis used the chi-square test, independent-samples t-test and receiver operating characteristic (ROC) analysis; $p < 0.05$ was significant. **Results:** Patients were predominantly young or middle-aged males (73.6%), and road traffic accidents were the commonest mechanism (58.5%). Subdural haematoma was the most frequent CT finding (73.6%). Favourable outcome occurred in 56.6% and unfavourable outcome in 43.4%; mortality was 17.0%. Categorical Helsinki and Rotterdam scores were not significantly associated with dichotomised GOSE outcome ($p = 0.552$ and $p = 0.362$) or mortality ($p = 0.419$ and $p = 0.484$). On ROC analysis, the Rotterdam score outperformed the Helsinki score for mortality (area under the curve [AUC] 0.785, $p < 0.001$ vs 0.699, $p = 0.012$), whereas both discriminated poorly for six-month outcome (AUC 0.557 and 0.533; both non-significant).**Conclusion:** The Rotterdam CT score predicted mortality better than the Helsinki score, but neither reliably predicted six-month functional outcome. CT scores should complement, not replace, integrated clinico-radiological assessment.

Keywords: Traumatic brain injury; Helsinki CT score; Rotterdam CT score; Glasgow Outcome Scale–Extended; Prognosis.

INTRODUCTION

Traumatic brain injury (TBI) is a major global public health concern that has been aptly described as a “silent epidemic” because of its substantial contribution to mortality, long-term disability and socioeconomic burden [1]. According to the Global Burden of Disease 2016 study, the global incidence and prevalence of TBI increased by 3.6% and 8.4%, respectively, between 1990 and 2016 [2], and more than 50 million people are estimated to sustain a TBI each year worldwide [3]. In developing countries such as India the burden is compounded by rapid urbanisation, increasing motor vehicle use, inadequate road-safety measures and limited access to advanced trauma care. Blunt TBI, resulting from road traffic accidents, falls and assaults, constitutes the majority of cases presenting to emergency departments and trauma centres.

Early and accurate assessment of injury severity is crucial for guiding management, prognostication, resource allocation and counselling. Clinical tools such as the Glasgow Coma Scale (GCS) are widely used to classify severity and estimate prognosis, but their reliability is compromised in patients who are intubated, sedated, intoxicated or have associated facial or spinal injuries, and they provide limited information on the underlying structural brain damage. Consequently, clinical assessment alone is insufficient for reliable outcome prediction, and objective radiological markers have been sought to strengthen prognostic models [4].

Computed tomography (CT) of the brain is the imaging modality of choice in the acute setting owing to its wide availability, rapid acquisition, high sensitivity for skull fractures and intracranial haemorrhage, and ability to guide immediate surgical and medical decisions [5]. CT

detects life-threatening lesions such as epidural, subdural and intracerebral haematomas and traumatic subarachnoid haemorrhage, and demonstrates secondary-injury markers including midline shift, basal-cistern compression and intraventricular haemorrhage, all of which correlate with intracranial pressure, cerebral perfusion and outcome.

To standardise CT-based assessment, several scoring systems have been developed. The Marshall classification was one of the earliest systems used to categorise brain injuries on CT [6], but it did not account for traumatic subarachnoid or intraventricular haemorrhage, both of which strongly influence outcome. The Rotterdam CT score was subsequently developed by Maas et al. as a refinement of the Marshall classification, incorporating basal-cistern status, degree of midline shift, presence of epidural haematoma, and traumatic subarachnoid or intraventricular haemorrhage into a simple, structured model [7].

Several studies have demonstrated the prognostic utility of the Rotterdam score. Huang et al. reported that it independently predicted outcome in head-injured patients undergoing decompressive craniectomy [8], and Liesemer et al. validated its ability to stratify mortality risk in paediatric TBI [9]. Yu et al. showed that the Rotterdam score reliably predicted six-month mortality and unfavourable outcome irrespective of the timing of the initial CT scan [10]. Despite its widespread use, the Rotterdam score differentiates specific lesion types poorly and predicts long-term functional outcome with limited precision.

To further improve prognostic accuracy, the Helsinki CT score was introduced in 2014 by Raj et al. [11]. It incorporates the type of mass lesion, lesion volume (>25 cm^3), intraventricular haemorrhage and suprasellar-cistern status, and applies lesion-specific weighting, including a negative score for epidural haematoma. Subsequent studies have evaluated its performance: Yao et al. found that the Helsinki score independently predicted long-term outcome with good discrimination [12]; Pargaonkar et al. concluded that, although the Marshall and Rotterdam scores predicted early mortality well, the Helsinki score offered improved accuracy for outcome prediction [13]; and Biuki et al. reported that the Rotterdam score was superior for predicting mortality whereas the Helsinki score showed higher sensitivity and negative predictive value for six-month outcome [14].

Although automated and semi-automated approaches to detecting TBI on CT are being explored, standardised visual scoring systems remain essential, particularly in resource-limited settings [15]. Despite multiple studies of individual CT scores, direct comparative analyses of the Helsinki and Rotterdam scores in blunt TBI are scarce, and prospective data from Indian tertiary centres using a standardised long-term outcome measure such as the Glasgow Outcome Scale–Extended (GOSE) are limited. The present prospective observational study was therefore undertaken to compare the accuracy and predictive value of the Helsinki and Rotterdam CT scores for six-month clinical outcome, and to determine which system offers superior predictive value in the local clinical setting.

MATERIALS AND METHODS

Study design and setting

This was a prospective observational analytical study conducted in the Trauma Care Centre, Department of Radiodiagnosis, Victoria Hospital, attached to Bangalore Medical College and Research Institute (BMCRI), Bengaluru, a tertiary care referral centre with a high case load of head-injury patients. The study was carried out over 18 months, from March 2024 to August 2025, and included phases for recruitment, imaging, data entry and six-month follow-up. Because the study involved neither intervention nor randomisation, it enabled a naturalistic assessment of the association between CT findings and six-month functional outcome. Reporting followed the STROBE and STARD recommendations as appropriate.

Participants

Consecutive eligible patients presenting with blunt TBI confirmed on clinical and imaging findings were enrolled. Inclusion criteria were age 18 years and above, blunt head injury referred for initial non-contrast CT brain evaluation, and written informed consent from the patient or a legal guardian. Exclusion criteria were anticoagulant therapy or coagulopathy; pre-existing intracranial pathology (tumour, hydrocephalus, congenital malformation); previous cranial surgery; death from causes other than TBI; penetrating head injury; non-traumatic impaired consciousness (e.g. metabolic coma, poisoning); and loss to follow-up at six months. A consecutive (non-probability) sampling technique was used, with every patient meeting the inclusion criteria enrolled prospectively after screening and consent until the required sample size was reached. Of the patients enrolled and imaged, those meeting the exclusion criteria or lost to six-month follow-up were not included in the final analysis, yielding 106 participants who completed follow-up and comprised the analysed cohort.

Sample size

The sample size was calculated using nMaster software version 2.0, based on sensitivity estimates derived from Biuki et al., in which the sensitivity of the Helsinki, Rotterdam and Stockholm scores for predicting mortality was 80%, 90% and 85%, respectively, and for predicting six-month outcome was 89%, 73% and 73%, respectively. Using a two-sided alpha of 0.05 and a precision of 6%, the estimated minimum sample size was

96 participants; allowing for a 10% dropout rate, the final target was 106 patients.

CT technique and scoring

All patients underwent non-contrast CT brain using either a 128-slice Philips Ingenuity Elite or a 32-slice Siemens Somatom scanner, with axial images acquired from skull base to vertex at 5-mm slice thickness according to standardised trauma protocols. Images were archived on the Picture Archiving and Communication System (PACS) and evaluated independently by two radiologists experienced in neuroimaging, blinded to clinical outcome; inter-observer discrepancies were resolved by consensus. Each scan was scored using both systems. The Rotterdam score ranged from 1 to 6 and integrated basal-cistern status, midline shift, presence of an epidural lesion and traumatic subarachnoid or intraventricular haemorrhage. The Helsinki score ranged from −3 to +14 and incorporated mass-lesion type (subdural, intracerebral or epidural haematoma), mass-lesion volume (>25 cm^3), intraventricular haemorrhage and suprasellar-cistern status (normal, compressed or obliterated); a representative scored study scan is shown in Figure 1. Demographic and clinical data — age, sex, mechanism of injury, admission GCS, duration of hospital stay and need for surgery — were recorded on a structured case record form. Outcome was assessed at six months using the GOSE, obtained by in-person or telephonic follow-up and verified by an independent reviewer, and was dichotomised into favourable (GOSE 5–8) and unfavourable (GOSE 1–4) outcome.

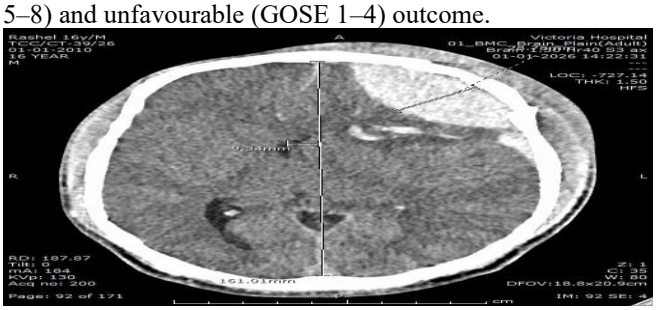

Figure 1. Representative axial non-contrast CT (NCCT) of the head in a study patient with blunt traumatic brain injury, illustrating features scored by both systems. There is an acute extradural haematoma (~2.8 cm) along the left frontal convexity producing mass effect — effacement of sulcal spaces, compression of the ipsilateral lateral ventricle, right uncal herniation and a ~9.3 mm midline shift to the right — together with bifrontal haemorrhagic contusions. Midline shift and the epidural mass lesion contribute to the Rotterdam score, while mass-lesion type contributes to the Helsinki score.

Statistical analysis

Data were analysed using the Statistical Package for the Social Sciences (SPSS) version 22.0. Continuous variables were summarised as mean ± standard deviation (SD), and categorical variables as frequencies and percentages. The chi-square test was used to compare categorical variables, and the independent-samples t-test to compare quantitative variables between favourable and unfavourable outcome groups. Sensitivity, specificity and predictive values were computed for each CT scoring system, and receiver operating characteristic (ROC) curves were plotted for the Helsinki and Rotterdam scores, with the area under the curve (AUC) calculated to assess discriminatory ability for both mortality and six-month outcome. A p value < 0.05 was considered statistically significant.

RESULTS

Baseline characteristics

A total of 106 patients with blunt TBI were analysed. The largest age group was 31–40 years (24.5%), followed by 18–30 years (22.6%); 72 of 106 patients (67.9%) were younger than 50 years. There was a marked male predominance (73.6% male, 26.4% female). Road traffic accidents were the commonest mechanism of injury (58.5%), followed by fall from height or self-fall (28.3%) and assault (13.2%). On admission, 39.6% of patients had mild (GCS 13–15), 32.1% moderate (GCS 9–12) and 28.3% severe (GCS ≤8) injury, so that 60.4% had moderate-to-severe TBI (Table 1).

CT findings and score distributions

Subdural haematoma was the most frequent CT finding (73.6%), followed by intracerebral haematoma (54.7%). Traumatic subarachnoid haemorrhage and intraventricular haemorrhage were each present in 39.6% of patients, midline shift ≥5 mm in 44.3% and epidural haematoma in 23.6% (Figure 7). The spectrum of these findings across representative study patients is illustrated in Figures 2–6. On the Helsinki score, 26.4% of
patients scored ≤2, 34.0% scored 3–6 and 39.6% scored ≥7; on the Rotterdam score, 28.3% scored 1–2, 37.7% scored 3–4 and 34.0% scored 5–6 (Table 2).

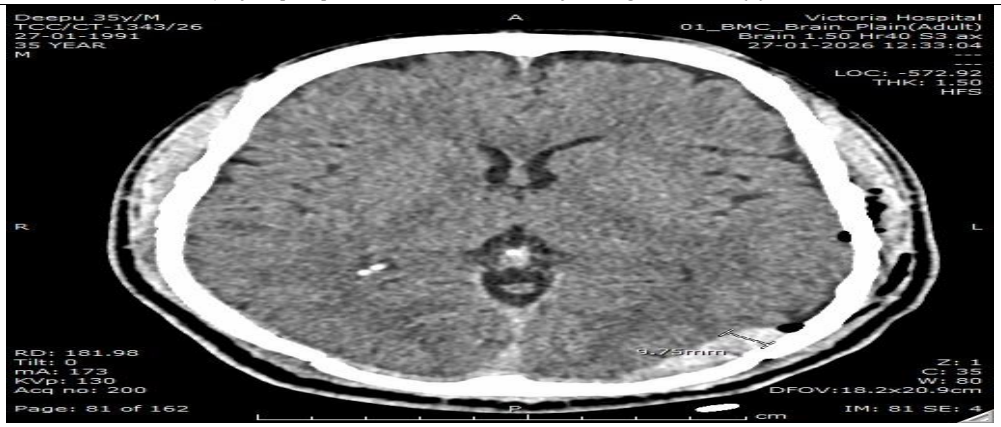

Figure 2. Axial NCCT of the head in a study patient showing an acute extradural haematoma with contained pockets of air along the left parietal and occipital convexities, measuring ~9.75 mm in maximum thickness. Epidural haematoma is a specifically weighted lesion in both scoring systems (negative weighting in the Helsinki score).

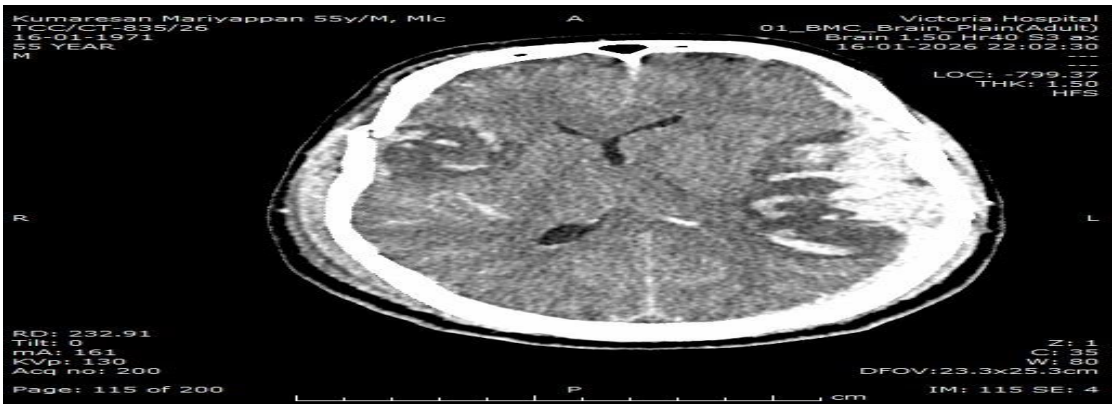

Figure 3. Axial NCCT of the head in a study patient demonstrating multifocal haemorrhagic contusions with surrounding oedema in the right fronto-temporal and left temporo-parietal lobes, with extension of haemorrhage into the lateral ventricles (intraventricular haemorrhage). Acute subdural haematoma is present along the falx and the left convexity, with subarachnoid haemorrhage in bilateral sulci and sylvian fissures, mass effect, subfalcine and uncal herniation and midline shift to the right. The subdural mass lesion, intraventricular and subarachnoid haemorrhage, midline shift and basal-cistern effacement all contribute to the Helsinki and Rotterdam scores.

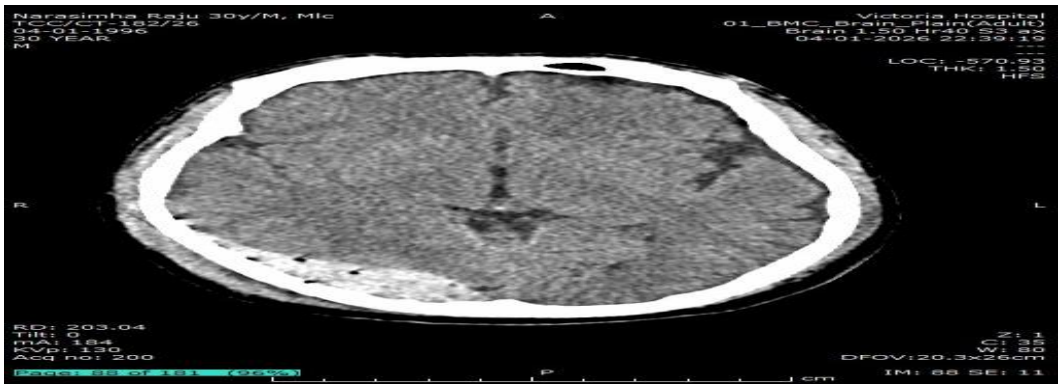

Figure 4. Axial NCCT of the head in a study patient showing an acute extradural haematoma in the right parieto-occipital convexity, measuring ~19.5 mm in maximum thickness, with mild mass effect (effacement of adjacent sulcal spaces). Epidural mass lesions are specifically weighted in both CT scoring systems.

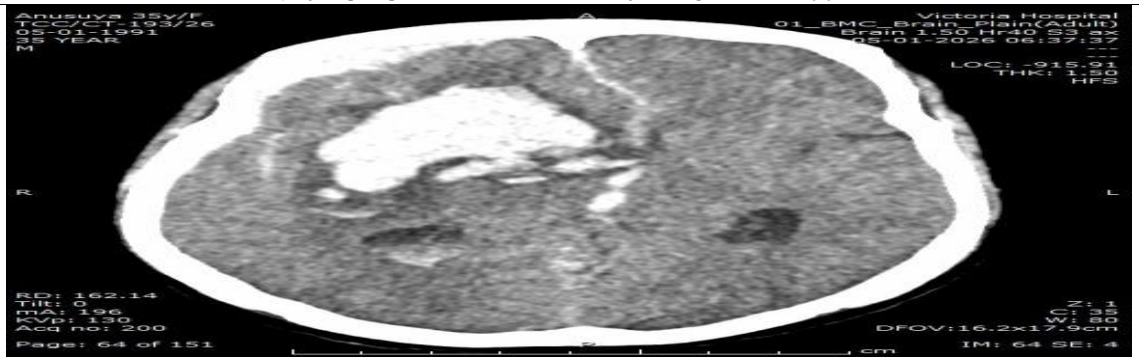

Figure 5. Axial NCCT of the head in a study patient showing a large acute haemorrhagic contusion with surrounding oedema in the right capsulo-ganglionic region, extending into the lateral ventricles (intraventricular haemorrhage), together with acute subdural haemorrhage along the right frontal convexity and falx and subarachnoid haemorrhage in bilateral sulci. There is pronounced mass effect with subfalcine and uncal herniation, midline shift to the left and diffuse effacement of the basal cisterns — features captured by the midline-shift, basal- cistern, intraventricular-haemorrhage and mass-lesion components of the Rotterdam and Helsinki scores.

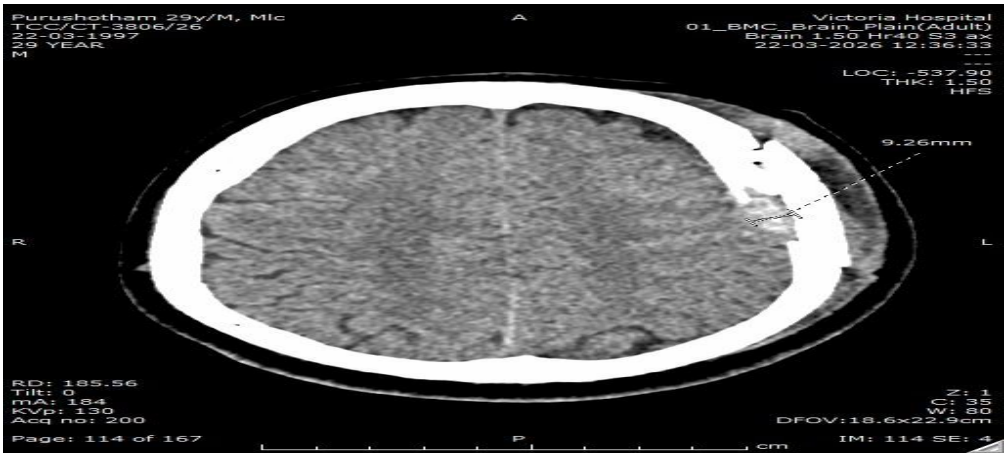

Figure 6. Axial NCCT of the head in a study patient showing an acute extradural haematoma (~9.26 mm maximum thickness) along the left frontal convexity with mild mass effect (effacement of adjacent sulcal spaces). The epidural lesion is a specifically weighted component of both the Helsinki and Rotterdam scores.

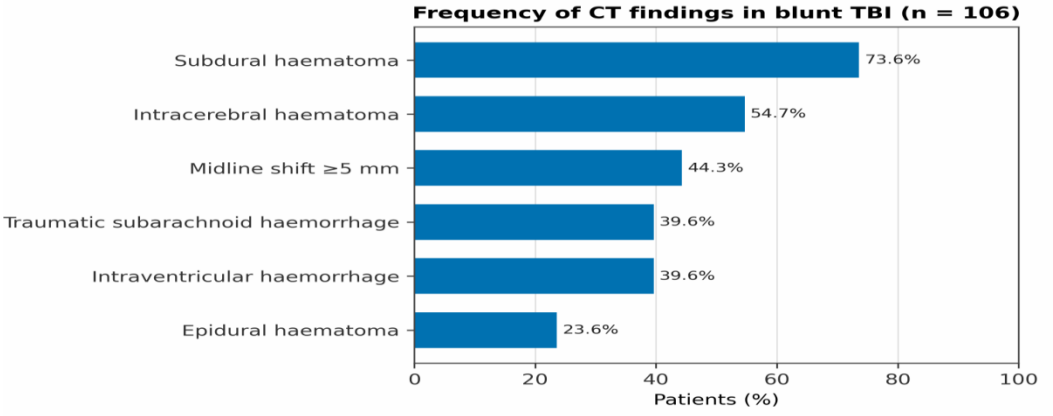

Figure 7. Frequency of individual CT findings at admission in the study cohort (n = 106), ranked from most to least common: subdural haematoma predominated (73.6%), followed by intracerebral haematoma (54.7%), midline shift ≥5 mm (44.3%), traumatic subarachnoid and intraventricular haemorrhage (39.6% each) and epidural haematoma (23.6%) (data from Table 2).

Table 1. Baseline demographic and clinical characteristics of study participants (n = 106).

Characteristic	Category	Frequency (n)	Percentage (%)
Age group (years)	18–30	24	22.6
	31–40	26	24.5
	41–50	22	20.8
	51–60	20	18.9
	>60	14	13.2
Sex	Male	78	73.6
	Female	28	26.4
Mechanism of injury	Road traffic accident	62	58.5
	Fall from height / self-fall	30	28.3
	Assault	14	13.2
Admission GCS severity	Mild (13–15)	42	39.6
	Moderate (9–12)	34	32.1
	Severe (≤8)	30	28.3

Table 2. Individual CT findings and distribution of Helsinki and Rotterdam CT scores (n = 106).

Parameter	Category	Frequency, n (%)
CT finding	Subdural haematoma	78 (73.6)
	Epidural haematoma	25 (23.6)
	Intracerebral haematoma	58 (54.7)
	Traumatic subarachnoid haemorrhage	42 (39.6)
	Intraventricular haemorrhage	42 (39.6)
	Midline shift ≥5 mm	47 (44.3)
Helsinki CT score	≤2	28 (26.4)
	3–6	36 (34.0)
	≥7	42 (39.6)
Rotterdam CT score	1–2	30 (28.3)
	3–4	40 (37.7)
	5–6	36 (34.0)

Table 3. Glasgow Outcome Scale–Extended (GOSE) outcome at six months (n = 106).

Outcome	Frequency (n)	Percentage (%)
Death	18	17.0
Vegetative state	6	5.7
Severe disability	22	20.8
Moderate disability	26	24.5
Good recovery	34	32.1
Unfavourable (GOSE 1–4)	46	43.4
Favourable (GOSE 5–8)	60	56.6

Six-month outcome

At six months, 32.1% of patients achieved good recovery, 24.5% had moderate disability, 20.8% severe disability, 5.7% remained in a vegetative state and 17.0% had died. After dichotomisation, 60 patients (56.6%) had a favourable outcome and 46 patients (43.4%) an
unfavourable outcome (Table 3; Figure 8).

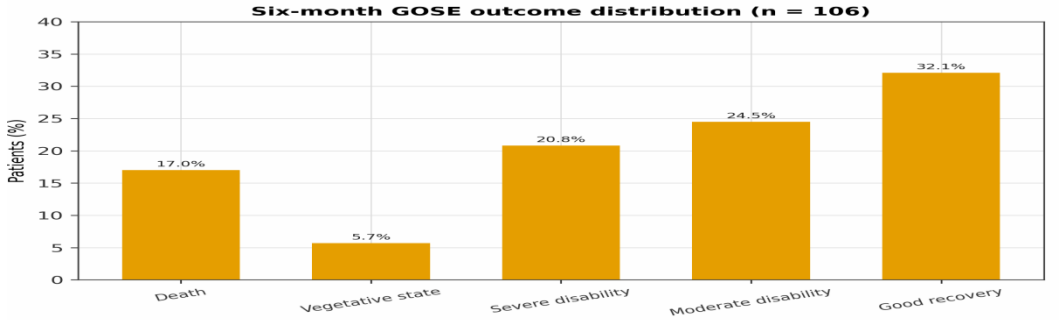

Figure 8. Distribution of six-month clinical outcome on the Glasgow Outcome Scale–Extended (GOSE) in the study cohort (n = 106): good recovery 32.1%, moderate disability 24.5%, severe disability 20.8%, vegetative state 5.7% and death 17.0% (data from
Table 3).

Table 4. Association between CT scores and dichotomised GOSE outcome at six months (n = 106).

CT score	Category	Unfavourable, n (%)	Favourable, n (%)	Total	Test statistic
Helsinki	≤2	13 (46.4)	15 (53.6)	28	$\chi^2 = 1.188$, df = 2, p = 0.552
	3–6	13 (36.1)	23 (63.9)	36	
	≥7	20 (47.6)	22 (52.4)	42	
Rotterdam	1–2	11 (36.7)	19 (63.3)	30	$\chi^2 = 2.031$, df = 2, p = 0.362
	3–4	16 (40.0)	24 (60.0)	40	
	5–6	19 (52.8)	17 (47.2)	36	

Table 5. Association between CT scores and mortality (n = 106).

CT score	Category	Alive, n (%)	Dead, n (%)	Total	Test statistic
Helsinki	≤2	21 (75.0)	7 (25.0)	28	$\chi^2 = 1.738$, df = 2, p = 0.419
	3–6	31 (86.1)	5 (13.9)	36	
	≥7	36 (85.7)	6 (14.3)	42	
Rotterdam	1–2	27 (90.0)	3 (10.0)	30	$\chi^2 = 1.451$, df = 2, p = 0.484
	3–4	32 (80.0)	8 (20.0)	40	
	5–6	29 (80.6)	7 (19.4)	36	

Table 6. Association between CT scores and admission GCS severity (n = 106).

CT score	Category	Mild, n (%)	Moderate, n (%)	Severe, n (%)	Test statistic
Helsinki	≤2	10 (35.7)	7 (25.0)	11 (39.3)	$\chi^2 = 4.047$, df = 4, p = 0.400
	3–6	14 (38.9)	15 (41.7)	7 (19.4)	
	≥7	18 (42.9)	12 (28.6)	12 (28.6)	
Rotterdam	1–2	8 (26.7)	13 (43.3)	9 (30.0)	$\chi^2 = 5.872$, df = 4, p = 0.209
	3–4	19 (47.5)	8 (20.0)	13 (32.5)	
	5–6	15 (41.7)	13 (36.1)	8 (22.2)	

Association of CT scores with outcome and mortality

Categorical Helsinki score was not significantly associated with dichotomised GOSE outcome: unfavourable outcome occurred in 46.4% of patients scoring ≤2, 36.1% scoring 3–6 and 47.6% scoring ≥7 ($\chi^2 = 1.188$, df = 2, p = 0.552). Similarly, the Rotterdam score showed a stepwise rise in unfavourable outcome from 36.7% (score 1–2) to 40.0% (score 3–4) to 52.8% (score 5–6), but this trend was not significant ($\chi^2 = 2.031$, df = 2, p = 0.362) (Table 4; Figure 9). Neither score was significantly associated with mortality: Helsinki ($\chi^2 = 1.738$, df= 2, p = 0.419) showed a paradoxically higher death rate in the lowest category (25.0% in ≤2 vs 13.9% in 3–6 and 14.3% in ≥7), whereas Rotterdam ($\chi^2 = 1.451$, df = 2, p = 0.484) showed mortality rising from 10.0% (score 1–2) to approximately 20% in higher categories (Table 5). Neither score was significantly associated with admission GCS severity (Helsinki $\chi^2 = 4.047$, df = 4, p = 0.400; Rotterdam $\chi^2 = 5.872$, df = 4, p = 0.209) (Table 6).

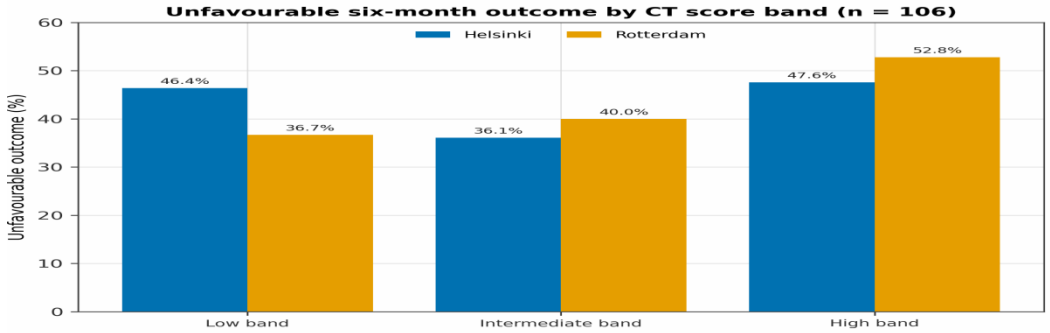

Figure 9. Proportion of patients with an unfavourable six-month outcome (GOSE 1–4) across ascending bands of the Helsinki (≤2, 3–6, ≥7) and Rotterdam (1–2, 3–4, 5–6) CT scores. Although the Rotterdam score showed a stepwise rise, neither categorical gradient reached statistical significance (Helsinki p = 0.552; Rotterdam p = 0.362) (data from Table 4).

Clinical associations and ROC analysis

Table 7. Clinical variables in relation to six-month outcome (n = 106).

Variable	Group	Value	Test statistic
Mean Helsinki CT score (mean ± SD)	Unfavourable (n = 46)	5.76 ± 4.06	t = 0.620, df = 104, p = 0.537
	Favourable (n = 60)	5.30 ± 3.58	
Hospital stay, days (mean ± SD)	Favourable (n = 60)	8.80 ± 2.30	t = 20.621, df = 104, p < 0.001
	Unfavourable (n = 46)	20.09 ± 3.33	
Need for surgery, unfavourable n (%)	No (n = 51)	22 (43.1)	χ^2 = 0.003, df = 1, p = 0.959
	Yes (n = 55)	24 (43.6)	
Admission GCS severity, unfavourable n (%)	Mild (n = 42)	17 (40.5)	χ^2 = 0.332, df = 2, p = 0.847
	Moderate (n = 34)	16 (47.1)	
	Severe (n = 30)	13 (43.3)	

Table 8. Receiver operating characteristic (ROC) analysis of Helsinki and Rotterdam CT scores for mortality and six-month outcome.

Endpoint	CT score	AUC	Standard error	95% CI	p value
Mortality	Helsinki	0.699	0.080	0.543–0.856	0.012
Mortality	Rotterdam	0.785	0.048	0.691–0.879	<0.001
Six-month outcome	Helsinki	0.533	0.080	0.377–0.689	0.674
Six-month outcome	Rotterdam	0.557	0.075	0.410–0.703	0.451

The mean Helsinki score did not differ significantly between the unfavourable (5.76 ± 4.06) and favourable (5.30 ± 3.58) outcome groups (t = 0.620, df = 104, p = 0.537). In contrast, mean hospital stay was markedly longer in patients with an unfavourable outcome (20.09 ± 3.33 days) than a favourable outcome (8.80 ± 2.30 days; t = 20.621, df = 104, p < 0.001). Neither the need for surgery (χ^2 = 0.003, df = 1, p = 0.959) nor admission GCS severity (χ^2 = 0.332, df = 2, p = 0.847) was significantly associated with six-month outcome (Table 7). On ROC analysis, the Rotterdam score discriminated mortality better than the Helsinki score (AUC 0.785, 95% CI 0.691–0.879, p < 0.001 vs AUC 0.699, 95% CI 0.543–0.856, p = 0.012), with sensitivity for mortality reaching 94.4% for Rotterdam and 88.9% for Helsinki at optimal cut-offs (Figures 10–12). For six-month functional outcome, both scores discriminated poorly and non-significantly (Helsinki AUC 0.533, 95% CI 0.377–0.689, p = 0.674; Rotterdam AUC 0.557, 95% CI 0.410–0.703, p = 0.451) (Table 8).

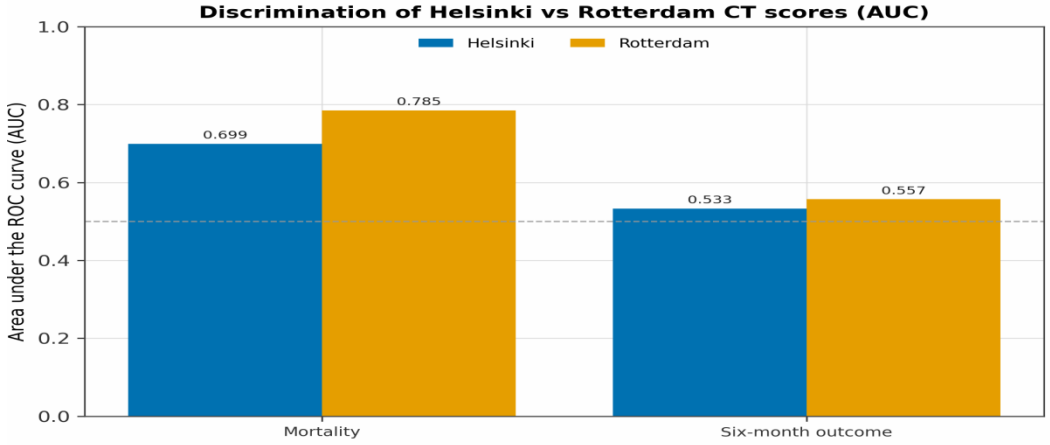

Figure 10. Comparison of discriminatory performance (area under the ROC curve, AUC) of the Helsinki and Rotterdam CT scores for mortality and six-month functional outcome. The Rotterdam score discriminated mortality better than the Helsinki score (AUC 0.785 vs 0.699), whereas both performed only marginally above chance (dashed line, AUC 0.5) for six-month outcome (0.557 vs 0.533) (data from Table 8).

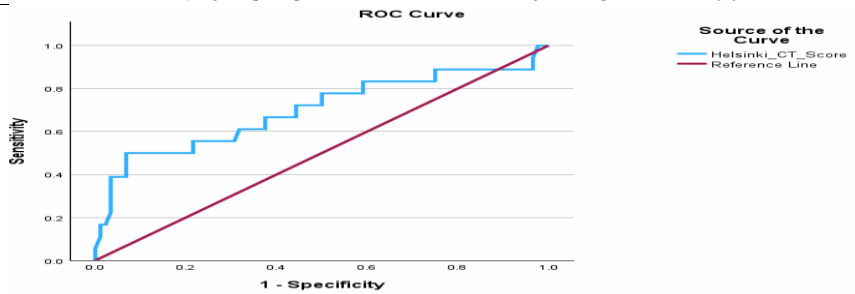

Figure 11. Receiver operating characteristic (ROC) curve of the Helsinki CT score for predicting mortality, from the study's own ROC analysis (AUC 0.699, standard error 0.080, p= 0.012).

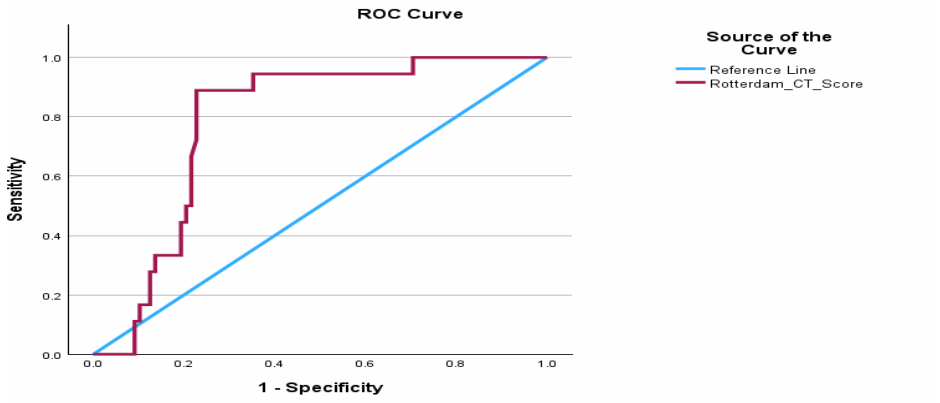

Figure 12. Receiver operating characteristic (ROC) curve of the Rotterdam CT score for predicting mortality, from the study's own ROC analysis (AUC 0.785, standard error 0.048, p< 0.001).

DISCUSSION

This prospective observational study compared the Helsinki and Rotterdam CT scores for predicting mortality and six-month outcome in 106 patients with blunt TBI. The cohort was predominantly young or middle-aged (67.9% younger than 50 years) and male (73.6%), consistent with the epidemiology of blunt TBI, in which economically productive men are disproportionately exposed to vehicular and occupational hazards. Direct demographic comparison with the supplied literature is limited because most comparative studies focused on prognostic performance rather than baseline epidemiology; nonetheless, Vehviläinen et al. reported a mean age of 46 ± 18 years in 703 ICU-admitted TBI patients [16], and Gurung et al. studied 92 adult blunt-TBI patients [17], indicating that CT-score validation cohorts are typically adult trauma populations comparable to ours.

Road traffic accidents were the commonest mechanism (58.5%), and 60.4% of patients had moderate-to-severe injury, providing an appropriate clinical background for CT-score comparison, as these scores are most informative in significant injury. Charry et al. specifically evaluated 243 patients with admission GCS ≤13 and found the Rotterdam score to correlate strongly with mortality and unfavourable outcome [18], while Mahmoud et al. restricted their 120-patient cohort to moderate-to-severe TBI (GCS ≤12) and reported strong outcome correlations for both scores [19]. Radiologically, subdural haematoma predominated (73.6%), and a large proportion of patients fell into higher Helsinki categories, reflecting substantial injury severity. This aligns conceptually with Raj et al., who emphasised that the Helsinki score improves discrimination by incorporating detailed lesion features such as intraventricular haemorrhage and suprasellar-cistern status [11], and with Saputri et al., whose pooled analysis attributed the Helsinki score's stronger long-term prognostic capacity to its inclusion of intraventricular haemorrhage and lesion volume [20].

The six-month outcome profile showed that 43.4% of patients either died or remained severely disabled, underscoring the considerable long-term burden of blunt TBI. The principal value of comparing the two scores lies in early identification of such unfavourable outcomes. In this respect, our categorical findings diverged from prior literature: neither the Helsinki score (χ^2 = 1.188, p = 0.552) nor the Rotterdam score (χ^2 = 2.031, p = 0.362) was significantly associated with dichotomised GOSE outcome. Biuki et al. reported that the Helsinki score had the highest sensitivity (89.8%) and a negative predictive value of 86.7% for six-month unfavourable outcome [14]; Yap found better overall discrimination for the Helsinki score (AUC 0.833 vs 0.805) with higher sensitivity (87.9% vs 78.8%) [21]; and Khormali et al. reported AUCs of 0.86 for Helsinki and 0.81 for Rotterdam for unfavourable outcome [22]. The absence

of a significant categorical association in our cohort may reflect sample-size limitations, loss of information from broad score categorisation, or population-specific heterogeneity rather than a true lack of score utility, a view supported by Raj et al. (outcome AUC 0.74–0.75 for Helsinki vs 0.63–0.70 for Rotterdam) [11] and Thelin et al., who demonstrated greater explanatory value for the Helsinki score (pseudo-R^2 0.18–0.22 vs 0.13–0.15) [23].

Mortality in our study was 17.0%, lower than the 25.6% ICU mortality reported by Vehviläinen et al. [16] and the 28% reported by Charry et al. in a GCS ≤13 cohort [18], implying a somewhat less severely injured population overall. The categorical Helsinki–mortality relationship was paradoxical, with the highest death proportion in the lowest score category, suggesting that broad categorisation obscured the prognostic value of the continuous score; Gurung et al., by contrast, found a clear mortality gradient (mean Helsinki 3.1 ± 1.4 in survivors vs 6.8 ± 1.9 in non-survivors) [17], and Mahmoud et al. reported 92.3% mortality sensitivity for the Helsinki score [19]. The Rotterdam score showed a more biologically intuitive mortality gradient (10.0% at score 1–2 rising to ~20% at higher scores), although this did not reach categorical significance ($\chi^2 = 1.451$, $p = 0.484$); prior work consistently supports the Rotterdam score as a robust mortality predictor, including Charry et al. (mean 4.7 ± 1.3 in non-survivors vs 3.2 ± 1.1 in survivors; AUC 0.86; odds ratio 2.13 per point) [18] and Biuki et al. (mortality sensitivity 90.1%, negative predictive value 97.3%) [14].

Neither score was significantly associated with admission GCS severity, which may be attributable to sedation, alcohol intake, timing of assessment, extracranial injuries or lesion location, all of which can alter GCS without a corresponding change in CT category. This is consistent with evidence that CT scores are most informative when combined with clinical variables: Raj et al. showed that the Helsinki score improved a base clinical model by +0.02 AUC ($p = 0.002$) whereas the Rotterdam score did not [11], and Gurung et al. found the Helsinki score to remain an independent predictor after adjustment for age and admission GCS ($p = 0.012$) [17]. Notably, hospital stay showed the strongest relationship with outcome (20.09 ± 3.33 days in unfavourable vs 8.80 ± 2.30 days in favourable outcome; $p < 0.001$), suggesting that dynamic in-hospital course may carry greater practical prognostic weight than baseline categorical scores, whereas need for surgery and admission GCS severity showed no significant association.

ROC analysis provided the most meaningful comparison and reconciled the non-significant categorical findings by preserving continuous information. The Rotterdam score discriminated mortality better than the Helsinki score (AUC 0.785, $p < 0.001$ vs 0.699, $p = 0.012$), concordant with Biuki et al. and Charry et al. [14,18]. However, the Helsinki mortality AUC of 0.699 was lower than the 0.84 reported by Vehviläinen et al. [16] and the 0.902 reported by Gurung et al. [17], and Mahmoud et al. found superior overall Helsinki performance (AUC 0.91 vs 0.87) [19]; thus, unlike several prior studies favouring the Helsinki score, our data support the Rotterdam score as the better mortality predictor, implying cohort-specific variation. For six-month functional outcome both scores performed only marginally above chance (Helsinki AUC 0.533; Rotterdam AUC 0.557), in contrast to Raj et al. [11], Yap [21], Khormali et al. [22], Saputri et al. (pooled AUC 0.84 vs 0.82; Helsinki significantly better, $p = 0.031$) [20] and Thelin et al. [23], suggesting that local case mix, sample size, dichotomisation method or follow-up variability influenced predictive yield in the present study.

STRENGTHS AND LIMITATIONS

The principal strengths of this study are its prospective design and the head-to-head comparison of two widely used CT scores within a single, uniformly assessed cohort of 106 blunt-TBI patients, which improved internal consistency. The study integrated radiological and clinical outcome measures — admission GCS, mortality, dichotomised GOSE at six months, hospital stay and need for surgery — and used appropriate statistical methods including the chi-square test, independent-samples t-test and ROC analysis, allowing assessment of both associations and discriminatory ability. Six-month follow-up captured functional recovery beyond hospital discharge, and the real-world case mix enhances clinical applicability.

Several limitations should be considered. First, the sample of 106 patients, though adequate for observational comparison, may have limited power to detect associations in categorical subgroup analyses, which may explain why clinically meaningful trends did not reach significance. Second, the single-centre design may limit generalisability. Third, broad categorisation of the CT scores may have caused loss of information, since continuous discrimination is often more sensitive than grouped analysis — a likely explanation for the divergence between the significant ROC results for mortality and the non-significant categorical analyses. Fourth, adjustment for other prognostic variables such as pupillary reactivity, hypotension, hypoxia, extracranial injuries and comorbidities was limited. Fifth, outcome was assessed only at six months, and inter-observer variability in CT interpretation was not formally quantified.

CONCLUSION

In this prospective observational study of 106 patients with blunt traumatic brain injury, the Rotterdam CT score demonstrated better discriminatory ability for mortality prediction (AUC 0.785, $p < 0.001$) than the Helsinki CT score (AUC 0.699, $p = 0.012$). However, both scoring systems performed poorly for predicting

six-month functional outcome (AUC 0.557 and 0.533, respectively; both non-significant), and neither showed a significant categorical association with dichotomised GOSE outcome, mortality or admission GCS severity. The Rotterdam CT score may therefore be preferred over the Helsinki score for early mortality risk stratification in blunt TBI, but neither should be used in isolation for long-term prognostication. The strong association between prolonged hospital stay and unfavourable outcome further suggests that dynamic clinical course adds prognostic information beyond baseline imaging. Larger, multicentre studies employing continuous CT scores and integrated clinico-radiological models are needed to refine outcome prediction in blunt TBI.

REFERENCES

1. Rusnak M. Traumatic brain injury: giving voice to a silent epidemic. Nat Rev Neurol. 2013;9:186–187.
2. GBD 2016 Traumatic Brain Injury and Spinal Cord Injury Collaborators. Global, regional, and national burden of traumatic brain injury and spinal cord injury, 1990–2016. Lancet Neurol. 2019;18:56–87.
3. Dewan MC, Rattani A, Gupta S, et al. Estimating the global incidence of traumatic brain injury. J Neurosurg. 2018;130:1080–1097.
4. Steyerberg EW, Mushkudiani N, Perel P, Butcher I, Lu J, McHugh GS, et al. Predicting outcome after traumatic brain injury: development and international validation of prognostic scores based on admission characteristics. PLoS Med. 2008;5(8):e165.
5. Zimmerman RA, Bilaniuk LT, Bruce D, et al. Computed tomography of head trauma. Radiology. 1978;126:403–408.
6. Marshall LF, Marshall SB, Klauber MR, et al. A new classification of head injury based on CT scan findings. J Neurosurg. 1991;75:S14–S20.
7. Maas AI, Hukkelhoven CW, Marshall LF, Steyerberg EW. Prediction of outcome in traumatic brain injury with computed tomographic characteristics. Neurosurgery. 2005;57:1173–1182.
8. Huang YH, Deng YH, Lee TC, Chen WF. Rotterdam computed tomography score as a prognosticator in head-injured patients undergoing decompressive craniectomy. Neurosurgery. 2012;71:80–85.
9. Liesemer K, Riva-Cambrin J, Bennett KS, Bratton SL, Tran H, Metzger RR, et al. Use of Rotterdam CT scores for mortality risk stratification in children with traumatic brain injury. Pediatr Crit Care Med. 2014;15:554–562.
10. Yu S, Choi HJ, Kim BC, Ha M, Kim K, Lee JH. Prognosis prediction in severe traumatic brain injury according to initial time of brain CT scan using the Rotterdam scoring system. Korean J Neurotrauma. 2022;18:161–168.
11. Raj R, Siironen J, Skrifvars MB, Hernesniemi J, Kivisaari R. Predicting outcome in traumatic brain injury: development of a novel CT classification system. Neurosurgery. 2014;75:632–646.
12. Yao S, Song J, Li S, Cao C, Fang L, Wang C, et al. Helsinki computed tomography scoring system can independently predict long-term outcome in traumatic brain injury. World Neurosurg. 2017;101:528–533.
13. Pargaonkar R, Kumar V, Menon G, Hegde A. Comparative study of CT scoring systems and predictors of early mortality in severe traumatic brain injury. J Clin Neurosci. 2019;66:100–106.
14. Biuki NM, Talari HR, Tabatabaei MH, Abedzadeh-Kalahroudi M, Akbari H, Esfahani MM, et al. Comparison of the predictive value of the Helsinki, Rotterdam, and Stockholm CT scores in predicting 6-month outcomes in patients with blunt traumatic brain injuries. Chin J Traumatol. 2023;26(6):357–362.
15. Vidhya V, Gudigar A, Raghavendra U, Hegde A, Menon GR, Molinari F, et al. Automated detection and screening of traumatic brain injury using computed tomography images. Int J Environ Res Public Health. 2021;18:6499.
16. Vehviläinen J, Skrifvars MB, Reinikainen M, Bendel S, Raj R. External validation of the Helsinki and Rotterdam computed tomography scoring systems for intensive care mortality prediction after traumatic brain injury. J Trauma Inj. 2022;35(4):245–253.
17. Gurung A, Pokharel P, Acharya N, Gautam S. Comparison of Helsinki and Rotterdam computed tomography scoring systems in predicting outcome in traumatic brain injury: a prospective observational study. Nepal J Neurosci. 2024;21(2):112–119.
18. Charry JD, Padilla-Zambrano HS, Moscote-Salazar LR, Alvis-Miranda HR. External validation of the Rotterdam CT scoring system in traumatic brain injury. Neurocirugia (Astur). 2017;28(6):271–276.
19. Mahmoud SS, Khalil A, El-Mazny A, Taha M, Abdelrahman H. Comparative evaluation of Helsinki, Rotterdam, and Marshall CT scoring systems in predicting outcomes of traumatic brain injury: a prospective cohort study. Egypt J Neurol Psychiatry Neurosurg. 2025;61(3):212–220.
20. Saputri AE, Priscila E, Praja RK, Ysrafil Y. Deciphering the effectiveness of computed tomography scoring systems in improving mortality prediction for traumatic brain injury: a systematic review and bibliometric analysis. J Trauma Inj. 2025;38(2):82–90.
21. Yap KE. Comparison of Helsinki and Rotterdam computed tomography scoring systems in predicting outcomes in traumatic brain injury. Asian J Neurosurg. 2021;16(3):655–662.
22. Khormali M, Soleimanipour S, Baigi V, Ehteram H, Talari H, Naghdi K, et al. Comparing predictive utility of head computed tomography scan-based scoring systems for traumatic brain injury: a retrospective study. Brain Sci. 2023;13(8):1145.

23. Thelin EP, Nelson DW, Bellander BM. A review of the existing CT scoring systems in traumatic brain injury: is there a need for a new CT score? PLoS Med. 2017;14(8):e1002368.