e-ISSN: 2722-3558

Sriwijaya Journal of Surgery

[SJS]

https://sriwijayasurgery.com

Predicting Postoperative Mortality in Head Injury Patients: Evaluating the Accuracy of Rotterdam Score

Fadhli Aufar Kasyfi[1*], Agung Muda Patih[2], Erial Bahar[3]

[1]Specialized Residency Training Program, Faculty of Medicine, Universitas Sriwijaya, Palembang, Indonesia

[2]Department of Neurosurgery, Faculty of Medicine, Universitas Sriwijaya, Palembang, Indonesia

[3]Department of Anatomy, Faculty of Medicine, Universitas Sriwijaya, Palembang, Indonesia

ARTICLE INFO

Keywords:
Head Injury
Mortality
Postoperative
Prognosis
Rotterdam score

***Corresponding author:**
Fadhli Aufar Kasyfi

E-mail address:
fadlix2@yahoo.com

All authors have reviewed and approved the final version of the manuscript.

https://doi.org/10.37275/sjs.v8i1.118

A B S T R A C T

Introduction: Head injury remains a leading cause of mortality and morbidity globally, necessitating accurate prognostic tools to guide clinical decision-making and inform patient outcomes. Rotterdam Score, a computed tomography (CT)-based scoring system, has shown promise in predicting mortality in head injury patients. This study aimed to evaluate the accuracy of the Rotterdam Score in predicting postoperative mortality in head injury patients undergoing surgery. **Methods:** A retrospective analysis was conducted on 56 head injury patients who underwent surgery at Dr. Mohammad Hoesin General Hospital, Palembang, between December 2023 and November 2024. Patient demographics, clinical characteristics, and CT scan findings were collected. Rotterdam Score was calculated for each patient, and its accuracy in predicting postoperative mortality was assessed using receiver operating characteristic (ROC) curve analysis. **Results:** The study cohort comprised 37 (66.1%) males and 19 (33.9%) females, with a mean age of 31.8 ± 21.6 years. Mild head injury was the most common Glasgow Coma Scale (GCS) classification (42.9%). The overall mortality rate was 17.8%. ROC curve analysis revealed an area under the curve (AUC) of 0.953 for the Rotterdam Score, with an optimal cut-off value of 4.5. Rotterdam Score demonstrated a sensitivity of 80%, specificity of 97.8%, positive predictive value (PPV) of 88.8%, and negative predictive value (NPV) of 95.7% in predicting postoperative mortality. **Conclusion:** The Rotterdam Score is a highly accurate predictor of postoperative mortality in head injury patients undergoing surgery. Its CT-based assessment allows for rapid and objective prognostication, aiding clinicians in risk stratification and treatment planning. Further research with larger and more diverse populations is warranted to validate these findings and establish the generalizability of Rotterdam Score across different healthcare settings.

1. Introduction

Head injury, encompassing a spectrum of traumatic brain injuries (TBIs), remains a pressing global health concern, casting a significant burden on individuals, families, and healthcare systems worldwide. Its far-reaching consequences extend beyond physical impairments, encompassing cognitive deficits, emotional and behavioral changes, and socioeconomic repercussions. The World Health Organization (WHO) estimates that TBIs contribute to a substantial portion of the world's mortality and disability burden, with approximately 69 million individuals sustaining a TBI each year. The incidence of head injury varies considerably across regions and populations, influenced by factors such as age, gender, socioeconomic status, and access to healthcare. In Europe, the estimated incidence of head injury is 235 cases per 100,000 population per year, highlighting the substantial impact of this condition on the region's healthcare system. Meanwhile, in Indonesia, head injuries account for 11.9% of all injury cases, underscoring the significant prevalence of this condition in the country. The severity of the head injury can range from mild concussions, characterized by transient neurological symptoms, to severe TBIs, resulting in prolonged unconsciousness, coma, or even death. The outcomes of head injury are equally diverse, spanning from complete recovery to persistent vegetative state, severe disability, or mortality.[1-4]

Accurate prognostication plays a pivotal role in the management of head injury patients, guiding clinical decision-making, optimizing treatment strategies, and providing realistic expectations to patients and their families. Early identification of high-risk individuals allows for timely interventions, potentially mitigating the severity of long-term sequelae. Moreover, accurate prognostic information aids in the allocation of healthcare resources, ensuring that patients receive the most appropriate level of care based on their individual needs and anticipated outcomes. Over the years, several prognostic tools have been developed to predict outcomes in head injury patients, each with its own strengths and limitations. The Glasgow Coma Scale (GCS), a widely used clinical assessment tool, provides a standardized measure of consciousness level based on eye-opening, verbal response, and motor response. While GCS is valuable for initial assessment and triage, its predictive ability for long-term outcomes, particularly in patients with severe head injuries who require sedation or intubation, is limited.[5-7]

The Marshall classification, a computed tomography (CT)-based system, categorizes head injuries based on the presence of mass lesions, midline shift, and cisternal compression. Although useful for predicting early mortality, the Marshall classification has limitations in assessing patients with multiple or diffuse injuries, which are often encountered in the context of head trauma. Rotterdam Score, a more recent CT-based scoring system, builds upon the Marshall classification by incorporating additional CT findings, such as epidural hematoma, intraventricular hemorrhage, and traumatic subarachnoid hemorrhage. This comprehensive assessment of CT scan findings, which reflect the severity and extent of brain injury, has positioned Rotterdam Score as a strong predictor of mortality and unfavorable outcomes in head injury patients.[8-10] This study aimed to evaluate the accuracy of the Rotterdam Score in predicting postoperative mortality in head injury patients undergoing surgery.

2. Methods

This retrospective study was conducted at Dr. Mohammad Hoesin General Hospital, a major tertiary care center located in Palembang, Indonesia. The hospital serves a diverse population, providing a wide range of medical and surgical services, including specialized care for patients with head injuries. Its neurosurgical department is equipped with state-of-the-art facilities, including advanced imaging technologies and a dedicated intensive care unit (ICU) for managing critically ill patients. The hospital's electronic medical record system provides a comprehensive database of patient information, facilitating the collection of detailed clinical data for research purposes. The study protocol was reviewed and approved by the Institutional Review Board of Dr. Mohammad Hoesin General Hospital, ensuring adherence to ethical guidelines and the protection of human subjects. Patient data were anonymized prior to analysis, removing any personally identifiable information to maintain confidentiality and comply with data privacy regulations.

The study population included all patients who underwent surgery for a head injury at Dr. Mohammad Hoesin General Hospital between December 2023 and November 2024. This timeframe was chosen to capture a representative sample of patients treated at the hospital, allowing for a comprehensive assessment of Rotterdam Score's accuracy in predicting postoperative mortality. Patients with incomplete medical records or missing CT scan data were excluded from the study to maintain data integrity and avoid potential biases. The inclusion criteria ensured that only patients with complete and reliable data were included in the analysis, enhancing the validity and generalizability of the study findings. Data were collected from electronic medical records and radiology reports, providing a comprehensive overview of each patient's clinical presentation, diagnostic findings, treatment course, and outcome. The electronic medical records contained detailed information on patient demographics, medical history, clinical assessments, surgical procedures, and postoperative complications. Radiology reports provided detailed descriptions of CT scan findings, including the presence and extent of various intracranial injuries. The following variables were extracted from the medical records and radiology reports; Demographics: Age, gender; Clinical characteristics: GCS score, type of surgery; CT scan findings: Midline shift, basal cisterns, epidural hematoma, intraventricular hemorrhage, traumatic subarachnoid hemorrhage; Outcome: Postoperative mortality.

Rotterdam Score was calculated for each patient based on their CT scan findings, using the following criteria; Basal cisterns: 0 points (normal), 1 point (compressed), 2 points (absent); Midline shift: 0 points (< 5 mm), 1 point (≥ 5 mm); Epidural hematoma: 0 points (absent), 1 point (present); Intraventricular hemorrhage or traumatic subarachnoid hemorrhage: 0 points (absent), 1 point (present). The total score ranges from 0 to 6, with higher scores indicating a worse prognosis. Rotterdam Score's calculation is based on objective CT scan findings, providing a standardized and reproducible assessment of head injury severity.

Data were analyzed using SPSS version 25 software, a comprehensive statistical package widely used in healthcare research. The software's advanced analytical capabilities allowed for a thorough examination of the data, enabling the assessment of Rotterdam Score's accuracy in predicting postoperative mortality. Descriptive statistics were used to summarize patient characteristics, providing an overview of the study population's demographic and clinical features. The distribution of variables, such as age, gender, GCS score, and type of surgery, was examined to understand the characteristics of the patient cohort. Receiver operating characteristic (ROC) curve analysis was performed to assess the accuracy of the Rotterdam Score in predicting postoperative mortality. The ROC curve is a graphical representation of a diagnostic test's performance, plotting the true positive rate (sensitivity) against the false positive rate (1-specificity) at various threshold settings. The area under the ROC curve (AUC) provides a summary measure of the test's accuracy, with higher AUC values indicating better discrimination. The optimal cut-off value for the Rotterdam Score was determined based on the Youden index, which maximizes the sum of sensitivity and specificity. This cut-off value represents the threshold at which the Rotterdam Score best distinguishes between patients who survive and those who die after surgery for head injury. Sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) were calculated to further evaluate Rotterdam Score's performance. Sensitivity measures the proportion of true positives correctly identified by the test, while specificity measures the proportion of true negatives correctly identified. PPV represents the probability of a patient having the condition given a positive test result, while NPV represents the probability of a patient not having the condition given a negative test result.

3. Results

Table 1 provides a detailed breakdown of the characteristics of the 56 head injury patients included in the study; Age: The patient population spans a wide age range, with the largest proportion (42.9%) falling within the 18-59 year age bracket. A significant number of patients were under 18 (41.1%), indicating that head injury affects both children and adults. A smaller proportion (16.1%) were elderly (60 years or older). This distribution suggests that the study captured a representative sample across different age groups commonly affected by head injuries; Gender: The majority of patients were male (66.1%), highlighting the known male predominance in head injury incidence; Glasgow Coma Scale (GCS): The GCS provides a measure of consciousness level. The distribution shows a fairly even split between mild (42.9%), moderate (33.9%), and severe (23.2%) head injuries based on GCS scores. This suggests that the study included patients across the spectrum of head injury severity; Type of Surgery: Craniotomy evacuation (42.9%) was the most common surgical procedure performed, followed by craniotomy decompression (25.0%). This reflects the types of surgical interventions often required to manage head injuries and their associated complications, such as intracranial hematomas and brain swelling. A smaller proportion of patients underwent combined craniotomy evacuation and decompression (17.9%). Other procedures, including craniotomy fracture elevation, VP shunt placement, and burr hole procedures, were less frequent; Distribution: Rotterdam Score, calculated from CT scan findings, ranged from 1 to 6. The most common scores were 3 (28.6%) and 4 (25.0%), indicating a moderate to high degree of injury severity in many patients. A small number of patients had a score of 6 (3.6%), which represents the most severe category on the Rotterdam Score; Mortality: The overall postoperative mortality rate was 17.9%, indicating that head injury, even with surgical intervention, carries a significant risk of death. This underscores the seriousness of the head injury and the need for accurate prognostic tools to guide treatment decisions and inform patients and families about potential outcomes.

Table 1. Patient characteristics.

Characteristic	**Category**	**Number of patients (n=56)**	**Percentage (%)**
Age (years)			
	<18	23	41.1
	18-59	24	42.9
	≥60	9	16.1
Gender			
	Male	37	66.1
	Female	19	33.9
Glasgow coma scale (GCS)			
	Mild (13-15)	24	42.9
	Moderate (9-12)	19	33.9
	Severe (3-8)	13	23.2
Type of surgery			
	Craniotomy Evacuation	24	42.9
	Craniotomy Decompression	14	25.0
	Craniotomy Evacuation + Decompression	10	17.9
	Craniotomy Fracture Elevation	6	10.7
	VP Shunt	1	1.8
	Burrhole	1	1.8
Rotterdam score			
	1	6	10.7
	2	11	19.6
	3	16	28.6
	4	14	25.0
	5	7	12.5
	6	2	3.6
Mortality			
	Alive	46	82.1
	Deceased	10	17.9

Table 2 presents the results of the statistical analysis examining the accuracy of Rotterdam Score in predicting postoperative mortality in head injury patients; Mean Rotterdam Score: The average Rotterdam Score in the study population was 3.2 ± 1.3. This indicates that, on average, patients had moderate to severe head injuries based on their CT scan findings; Area Under the ROC Curve (AUC): The AUC is a key measure of a diagnostic test's ability to discriminate between two outcomes (in this case, survival vs. mortality). An AUC of 0.953 is exceptionally high, indicating that Rotterdam Score has excellent discriminatory power in predicting postoperative mortality in this patient group. An AUC of 1.0 represents perfect discrimination, while 0.5 represents no better than chance; Optimal Cut-off Value: The optimal cut-off value for the Rotterdam Score was determined to be 4.5. This means that a Rotterdam Score of 4.5 or higher is the threshold that best separates patients who are likely to die after surgery from those who are likely to survive; Sensitivity: A sensitivity of 80% means that Rotterdam Score correctly identified 80% of the patients who actually died after surgery. In other words, 80% of patients who died had a Rotterdam Score of 4.5 or higher; Specificity: A specificity of 97.8% means that Rotterdam Score correctly identified 97.8% of the patients who actually survived after surgery. In other words, 97.8% of patients who survived had a Rotterdam Score lower than 4.5; Positive Predictive Value (PPV): A PPV of 88.8% means that if a patient had a Rotterdam Score of 4.5 or higher, there was an 88.8% probability that they would die after surgery; Negative Predictive Value (NPV): An NPV of 95.7% means that if a patient had a Rotterdam Score lower than 4.5, there was a 95.7% probability that they would survive after surgery.

Table 2. Accuracy of Rotterdam score in predicting postoperative mortality.

Metric	Value
Mean Rotterdam Score	3.2 ± 1.3
Area Under the ROC Curve (AUC)	953
Optimal Cut-off Value	4.5
Sensitivity	80%
Specificity	97.8%
Positive Predictive Value (PPV)	88.8%
Negative Predictive Value (NPV)	95.7%

Table 3 presents the results of a multivariate analysis, which examines the independent association of various factors with postoperative mortality in head injury patients. This type of analysis helps determine which factors have a significant impact on mortality after accounting for the influence of other variables. The odds ratio (OR) of 0.968 suggests that for each one-year increase in age, the odds of postoperative mortality decrease slightly. However, with a p-value of 0.103, this association is not statistically significant. This means that age, in this study, was not an independent predictor of mortality after accounting for other factors. The OR of 0.273 suggests that males have lower odds of postoperative mortality compared to females. However, this finding is also not statistically significant (p=0.178), indicating that gender does not independently predict mortality in this model. GCS Classification; Mild (13-15): This category serves as the reference group for comparison; Moderate (9-12): Compared to patients with mild head injury, those with moderate head injury have significantly lower odds of mortality (OR=0.133, p=0.005); Severe (3-8): Similar to moderate head injury, patients with severe head injury also have significantly lower odds of mortality compared to those with mild head injury (OR=0.133, p=0.005). This finding seems counterintuitive at first glance. However, it likely reflects the fact that patients with more severe GCS scores (moderate and severe) may receive more aggressive interventions and monitoring, potentially improving their chances of survival despite the severity of their injury. The OR of 0.715 suggests that the type of surgery performed is not significantly associated with postoperative mortality (p=0.343). This indicates that the choice of surgical procedure, within the range of procedures performed in this study, did not independently influence mortality risk.

Table 3. Multivariate analysis of factors associated with postoperative mortality.

Variable	Odds Ratio (OR)	95% Confidence Interval (CI)	p-value
Age (years)	968	0.93 - 1.00	0.103
Gender (Male vs. Female)	273	0.41 - 1.80	0.178
GCS classification			
Mild (13-15)	Ref	-	-
Moderate (9-12)	133	0.33 - 0.54	**0.005**
Severe (3-8)	133	0.33 - 0.54	**0.005**
Type of surgery	715	0.35 - 1.43	0.343

4. Discussion

Rotterdam Score's exceptional accuracy in predicting postoperative mortality among head injury patients stems from its comprehensive assessment of computed tomography (CT) scan findings, which effectively encapsulate the severity and extent of brain injury. By incorporating key indicators such as epidural hematoma, intraventricular hemorrhage, and traumatic subarachnoid hemorrhage—in addition to the foundational elements of the Marshall classification—the Rotterdam Score demonstrates enhanced predictive capabilities compared to other prognostic tools. Our results strongly align with previous studies that have illuminated the prognostic significance of Rotterdam Score in head injury patients. Notably, one study reported a sensitivity of 84.2% and a specificity of 96.2% for Rotterdam Score in predicting unfavorable outcomes, employing a cut-off value of 4. Another study identified a statistically significant correlation between Rotterdam Score and mortality at 2 weeks, 1 month, and 3 months after head injury. These convergent findings underscore the robustness and generalizability of Rotterdam Score as a prognostic tool across diverse clinical settings. CT scans provide objective and detailed information about the nature and extent of brain injury, unlike clinical assessments like the Glasgow Coma Scale (GCS), which rely on subjective observations that can be influenced by sedation, intubation, or other confounding factors. CT scans allow for the visualization of intracranial structures, including the presence and extent of various injuries such as contusions, hematomas, edema, and midline shift. These findings are crucial in assessing the severity of brain injury and its potential impact on patient outcomes. CT scans can also aid in the early detection of complications such as herniation, hydrocephalus, and cerebral ischemia, which can significantly influence mortality risk. CT scans enable the quantitative assessment of brain injury, such as measuring the volume of hematomas or the degree of midline shift. This quantitative information provides a more precise assessment of injury severity compared to qualitative observations alone. CT scans are widely available in most healthcare settings and can be performed rapidly, facilitating timely diagnosis and prognostication in acute head injury cases. CT scans allow for multiplanar imaging, enabling the visualization of brain injury in different planes (axial, coronal, and sagittal). This multiplanar perspective provides a more comprehensive understanding of the injury and its potential impact on brain function. CT scan data can be used to create 3D reconstructions of the brain, providing a detailed visualization of the injury and its relationship to surrounding structures. This 3D perspective can aid in surgical planning and intervention. The presence of an epidural hematoma, a collection of blood between the skull and the outer layer of the brain, is a strong predictor of mortality in head injury patients. Rotterdam Score incorporates this indicator, recognizing its significant impact on patient outcomes. The size and location of an epidural hematoma can significantly influence its impact on mortality risk. Larger hematomas and those located in critical brain regions are associated with worse outcomes. The time elapsed between injury and surgical evacuation of an epidural hematoma is also a crucial factor in determining patient outcomes. Prompt surgical intervention can significantly improve survival rates. The density and morphology of an epidural hematoma on CT scan can provide insights into its chronicity and potential for expansion. Hyperdense hematomas with a convex shape are often associated with higher acuity and increased risk. Intraventricular hemorrhage, bleeding into the ventricles of the brain, is another critical indicator of severe brain injury and is associated with a high mortality risk. Rotterdam Score includes this indicator, further enhancing its predictive accuracy. The extent of intraventricular hemorrhage, as measured by the volume of blood in the ventricles, is correlated with mortality risk. Larger hemorrhages are associated with worse outcomes. Intraventricular hemorrhage can lead to hydrocephalus, an abnormal buildup of cerebrospinal fluid in the brain, which can further increase intracranial pressure and worsen outcomes. The location and cast of intraventricular hemorrhage can provide clues about the underlying cause and potential complications. For example, a blood clot in the third ventricle may obstruct the flow of cerebrospinal fluid, leading to hydrocephalus. Traumatic subarachnoid hemorrhage, bleeding into the space between the brain and the surrounding membranes, is a common finding in head injury patients and can contribute to increased intracranial pressure and mortality. Rotterdam Score incorporates this indicator, recognizing its potential impact on patient outcomes. The distribution and thickness of traumatic subarachnoid hemorrhage can influence its impact on mortality risk. Diffuse and thick subarachnoid hemorrhage is associated with worse outcomes. Traumatic subarachnoid hemorrhage can lead to vasospasm, a narrowing of blood vessels in the brain, which can cause cerebral ischemia and further increase mortality risk. Traumatic subarachnoid hemorrhage may be associated with intracranial aneurysms, which are weakened and bulging blood vessels in the brain that can rupture and cause further bleeding. Rotterdam Score builds upon the Marshall classification, a well-established CT-based system for categorizing head injuries based on the presence of mass lesions, midline shift, and cisternal compression. By incorporating additional CT findings and refining the scoring system, Rotterdam Score enhances the predictive accuracy of the Marshall classification, providing a more comprehensive assessment of head injury severity. Both the Marshall classification and Rotterdam Score rely on objective CT scan findings, minimizing interobserver variability and ensuring reproducibility of assessments across different healthcare providers. The Marshall classification has been widely used in clinical practice and research, providing a valuable foundation for the development of Rotterdam Score. Rotterdam Score's comprehensive assessment of CT scan findings and incorporation of key indicators contribute to its superior predictive capabilities compared to clinical scoring systems like GCS. Rotterdam Score allows for accurate risk stratification of head injury patients, enabling clinicians to identify those at high risk of mortality and tailor treatment strategies accordingly. Accurate risk stratification facilitates early and targeted interventions for high-risk patients, potentially mitigating the severity of long-term sequelae and improving functional outcomes. Rotterdam Score aids in informed decision-making regarding surgical intervention, ensuring that those who stand to benefit most are prioritized. Rotterdam Score provides valuable prognostic information that can be used to counsel patients and their families about the potential outcomes of head injury. By facilitating early identification of high-risk patients and guiding timely interventions, Rotterdam Score has the potential to improve patient outcomes and reduce mortality rates. Rotterdam Score's accurate prognostication can lead to a reduction in mortality rates by enabling timely and aggressive management of high-risk patients. Early identification of patients at risk of unfavorable outcomes allows for the implementation of interventions aimed at minimizing long-term sequelae and maximizing functional recovery. Rotterdam Score can aid in the efficient allocation of healthcare resources by identifying patients who require more intensive monitoring and treatment.[11-13]

The CT-based assessment inherent in Rotterdam Score confers several advantages over clinical scoring systems such as the Glasgow Coma Scale (GCS). CT scans furnish objective and granular information regarding the nature and extent of brain injury, while GCS is inherently reliant on subjective observations that can be confounded by sedation, intubation, or other extraneous factors. Furthermore, Rotterdam Score's simplicity and ease of calculation render it a pragmatic tool for clinicians. Its standardized approach minimizes inter-observer variability, ensuring consistency in prognostication across different healthcare providers. This attribute is particularly valuable in time-sensitive emergency settings, where rapid and accurate risk stratification is paramount. Rotterdam Score is based on objective CT scan findings, eliminating the subjectivity inherent in clinical assessments like GCS. This objectivity ensures that the score is not influenced by observer bias or interpretation, leading to more consistent and reliable prognostication. Rotterdam Score provides a standardized assessment of head injury severity, allowing for comparisons across different patients and healthcare settings. This standardization facilitates research and quality improvement initiatives aimed at optimizing the management of head injuries. The objective nature of Rotterdam Score ensures reproducibility of assessments across different healthcare providers. This reproducibility enhances the reliability of prognostication and facilitates communication among clinicians involved in patient care. Rotterdam Score utilizes quantitative measurements from CT scans, such as the degree of midline shift and the presence or absence of specific intracranial injuries. This quantitative approach provides a more precise and objective assessment of injury severity compared to qualitative clinical observations. Rotterdam Score incorporates a comprehensive assessment of CT scan findings, including the presence and extent of various injuries such as epidural hematoma, intraventricular hemorrhage, traumatic subarachnoid hemorrhage, midline shift, and basal cistern compression. This multifaceted evaluation provides a more complete picture of head injury severity compared to clinical assessments that focus on a limited number of parameters. The comprehensive nature of Rotterdam Score contributes to its enhanced predictive accuracy compared to other prognostic tools. By considering a wider range of CT scan findings, Rotterdam Score captures a more complete picture of the injury and its potential impact on patient outcomes. Rotterdam Score incorporates key indicators of severe brain injury, such as epidural hematoma, intraventricular hemorrhage, and traumatic subarachnoid hemorrhage. These indicators are strong predictors of mortality and morbidity, and their inclusion in Rotterdam Score enhances its prognostic value. Rotterdam Score builds upon the Marshall classification, a well-established CT-based system for assessing head injury severity. This integration leverages existing knowledge and refines the scoring system for improved prognostication. Rotterdam Score is simple to calculate, requiring only the assessment of a few key CT scan findings. This simplicity allows for rapid prognostication, which is crucial in time-sensitive emergency settings. The ease of use of Rotterdam Score means that clinicians require minimal training to implement it in their practice. This ease of adoption facilitates the widespread use of Rotterdam Score and its integration into routine head injury assessment protocols. The simplicity of Rotterdam Score reduces the cognitive burden on clinicians, particularly in high-pressure emergency situations. This allows clinicians to focus on other critical aspects of patient care without being overwhelmed by complex scoring systems. Rotterdam Score utilizes clear and concise criteria for assigning points based on CT scan findings. This clarity minimizes ambiguity and promotes consistency in scoring across different clinicians. Rotterdam Score allows for accurate risk stratification of head injury patients, enabling clinicians to identify those at high risk of mortality and morbidity. This risk stratification facilitates informed decision-making regarding treatment strategies and resource allocation. Rotterdam Score's accurate prognostication enables early and targeted interventions for high-risk patients. This can potentially mitigate the severity of long-term sequelae and improve functional outcomes. By facilitating early identification of high-risk patients and guiding timely interventions, Rotterdam Score has the potential to improve patient outcomes and reduce mortality rates. Rotterdam Score provides valuable prognostic information that can be used to counsel patients and their families about the potential outcomes of head injury. This information can help patients and families make informed decisions about treatment options and long-term care. Rotterdam Score can aid in triage decisions, ensuring that patients with more severe injuries are prioritized for immediate medical attention and resources. Rotterdam Score has been shown to be accurate and reliable in diverse healthcare settings, including trauma centers, community hospitals, and rural clinics. This generalizability makes it a valuable tool for head injury assessment across a wide range of healthcare environments. Rotterdam Score has been validated in different patient populations, including adults and children, with varying severities of head injury. This validation supports its use in a broad spectrum of head injury cases. Rotterdam Score has been adopted by clinicians and researchers internationally, demonstrating its relevance and applicability across different healthcare systems and cultural contexts. Rotterdam Score's reliance on CT scan findings makes it adaptable to technological advancements in medical imaging. As CT technology continues to evolve, Rotterdam Score can potentially incorporate new imaging parameters and refine its prognostic capabilities.[14-16]

In our study, GCS classification emerged as the sole factor independently associated with postoperative mortality. This finding underscores the enduring importance of GCS in the initial assessment and triage of head injury patients, even though its predictive capacity for long-term outcomes may be limited. GCS, despite its limitations, remains a cornerstone of neurological assessment due to its widespread familiarity and ease of use. It serves as a valuable adjunct to Rotterdam Score, providing a complementary clinical perspective that informs holistic patient management. GCS provides a rapid and standardized assessment of consciousness level in head injury patients. Its simplicity and ease of use make it an ideal tool for initial assessment in emergency settings, where rapid triage and prioritization of care are crucial. GCS assesses three key components of neurological status, eye-opening, verbal response, and motor response. These components provide a snapshot of the patient's level of consciousness and neurological function, aiding in the initial assessment of injury severity. GCS scores can be used to triage patients and allocate resources accordingly. Patients with lower GCS scores, indicating more severe injury, are typically prioritized for immediate medical attention and more intensive monitoring. GCS scores guide initial management decisions, such as the need for airway support, intubation, or immediate neurosurgical intervention. Lower GCS scores often necessitate more aggressive interventions to stabilize the patient and prevent further neurological deterioration. GCS provides a clinical perspective that complements the objective CT scan findings used in Rotterdam Score. While Rotterdam Score focuses on the structural aspects of brain injury, GCS assesses the functional impact of the injury on the patient's level of consciousness. The combination of GCS and Rotterdam Score provides a more holistic view of the patient's condition, informing clinical decision-making and patient management. By considering both the structural and functional aspects of brain injury, clinicians can tailor treatment strategies to the individual needs of each patient. GCS can be used to monitor changes in the patient's neurological status over time. This monitoring can help detect early signs of deterioration or improvement, guiding adjustments in treatment plans and interventions. While GCS may have limitations in predicting long-term outcomes in all head injury patients, it can still provide valuable prognostic information in specific contexts. For example, GCS has been shown to be a strong predictor of outcome in patients with mild traumatic brain injury. GCS relies on subjective observations of the patient's responses, which can be influenced by factors such as sedation, intubation, or pre-existing neurological conditions. This subjectivity can introduce variability in scoring and potentially affect the accuracy of prognostication. While GCS is valuable for initial assessment and triage, its predictive capacity for long-term outcomes, particularly in patients with severe head injuries who require sedation or intubation, is limited. GCS should not be used as a substitute for CT scan assessment in head injury patients. CT scans provide crucial information about the structural aspects of brain injury, which are essential for accurate prognostication and treatment planning. GCS scores can be influenced by extraneous factors such as hypoxia, hypotension, and hypoglycemia. It is essential to address these factors promptly to ensure an accurate assessment of the patient's neurological status. Despite its limitations, GCS remains a cornerstone of neurological assessment due to its widespread familiarity and ease of use. It is a universally recognized tool that facilitates communication and collaboration among healthcare providers involved in the care of head injury patients. GCS serves as a valuable adjunct to advanced imaging techniques such as CT scans and MRI. While imaging provides detailed structural information, GCS offers a rapid and readily available assessment of neurological function. Ongoing research and refinement of GCS aim to improve its accuracy and address its limitations. This continuous improvement ensures that GCS remains a relevant and valuable tool in the assessment and management of head injury patients. GCS is often integrated into clinical pathways and protocols for the management of head injury patients. This integration ensures that GCS is used consistently and systematically in clinical practice, promoting standardized care and improved patient outcomes.[17,18]

Rotterdam Score's exceptional accuracy and practicality have far-reaching implications for clinical practice. By accurately identifying high-risk patients, clinicians can tailor treatment strategies, optimize resource allocation, and facilitate informed decision-making in collaboration with patients and their families. Early prognostication using Rotterdam Score enables timely interventions, potentially mitigating the severity of long-term sequelae and improving functional outcomes. Moreover, it aids in the judicious selection of patients for surgical intervention, ensuring that those who stand to benefit most are prioritized. Rotterdam Score's exceptional accuracy in predicting postoperative mortality allows for enhanced risk stratification of head injury patients. This accurate prognostication enables clinicians to identify high-risk patients who may require more aggressive monitoring and treatment. By accurately identifying high-risk patients, clinicians can tailor treatment strategies to the individual needs of each patient. This may involve closer monitoring, more frequent neurological assessments, and earlier intervention for complications. Rotterdam Score can aid in optimizing resource allocation by identifying patients who require more intensive care and those who may be suitable for less intensive management. This can help ensure that resources are used efficiently and effectively. Rotterdam Score, in conjunction with other clinical data, allows for a more individualized approach to patient care. This means that treatment plans can be tailored to the specific needs and risks of each patient, rather than relying on a one-size-fits-all approach. Rotterdam Score enables the early identification of high-risk patients, allowing for timely interventions that may potentially mitigate the severity of long-term sequelae. Timely interventions can help prevent secondary brain injury, which refers to the damage that occurs after the initial injury due to factors such as swelling, ischemia, and infection. By facilitating early and targeted interventions, Rotterdam Score can contribute to improved functional outcomes for head injury patients. This may involve a reduction in long-term disability, improved cognitive function, and enhanced quality of life. Early identification of high-risk patients allows for proactive measures to prevent and manage potential complications, such as seizures, infections, and respiratory problems. Rotterdam Score provides valuable prognostic information that can be used to facilitate shared decision-making between clinicians, patients, and their families. This shared decision-making approach ensures that patients and families are actively involved in treatment decisions and that their preferences and values are considered. Rotterdam Score can help set realistic expectations about the potential outcomes of head injury. This can help patients and families prepare for the challenges of recovery and make informed decisions about long-term care. Rotterdam Score can aid in ethical decision-making, particularly in cases where treatment options may be limited or have significant risks. By providing accurate prognostic information, Rotterdam Score can help clinicians and families make difficult decisions about the continuation or withdrawal of life-sustaining treatment. Rotterdam Score can initiate discussions about advanced care planning, allowing patients and families to express their wishes regarding medical treatment and end-of-life care. Rotterdam Score aids in the judicious selection of patients for surgical intervention. By accurately predicting postoperative mortality risk, Rotterdam Score can help identify patients who are most likely to benefit from surgery. Rotterdam Score can help minimize surgical risks by ensuring that only patients who are likely to benefit from surgery are selected for the procedure. This can help reduce the incidence of unnecessary surgeries and associated complications. Rotterdam Score can aid in optimizing the timing of surgical intervention. In some cases, delaying surgery may be appropriate to allow for further stabilization of the patient or to address other medical issues before proceeding with the operation. Rotterdam Score, in conjunction with other clinical and imaging data, can guide the surgical approach and technique, helping surgeons choose the most appropriate and effective procedures. Rotterdam Score can be integrated into clinical pathways and protocols for the management of head injury patients. This integration can help standardize care and ensure that all patients receive timely and appropriate assessments and interventions. Rotterdam Score can be used as a quality improvement tool to monitor the outcomes of head injury patients and identify areas for improvement in care delivery. Rotterdam Score can be used in research to further evaluate its prognostic capabilities and explore its potential applications in different clinical settings and patient populations. Rotterdam Score can be used in clinical trials to stratify patients and assess the effectiveness of new treatments and interventions for head injury.[19,20]

5. Conclusion

In conclusion, this study underscores the exceptional accuracy of Rotterdam Score in predicting postoperative mortality among head injury patients undergoing surgery. Its reliance on objective CT scan findings, incorporating key indicators of brain injury severity, confers a distinct advantage over traditional clinical assessments. Rotterdam Score's capacity to accurately stratify patients according to risk enables clinicians to make informed decisions regarding surgical intervention, prioritize high-risk individuals for more intensive monitoring and treatment, and optimize the allocation of healthcare resources. Furthermore, the simplicity and reproducibility of Rotterdam Score make it an invaluable tool for clinicians across diverse healthcare settings. Its standardized approach minimizes inter-observer variability, ensuring consistency in prognostication and facilitating communication among healthcare providers. Rotterdam Score's ability to furnish rapid and accurate prognostic information empowers clinicians to initiate timely interventions, potentially mitigating the severity of long-term sequelae and improving functional outcomes for head injury patients. Looking forward, further research with larger and more diverse patient populations is warranted to validate these findings and establish the generalizability of Rotterdam Score across different healthcare settings. As technology advances, Rotterdam Score's reliance on CT scan findings makes it adaptable to incorporate new imaging parameters and refine its prognostic capabilities. The integration of Rotterdam Score into clinical pathways and protocols can help standardize care and ensure that all patients receive timely and appropriate assessments and interventions. Moreover, Rotterdam Score can serve as a valuable tool for quality improvement and research, further enhancing our understanding of head injury and its management.

6. References

1. 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): 357–62.
2. Amakhian AO, Obi-Egbedi-Ejakpovi EB, Morgan E, Adeyekun AA, Abubakar MM. Correlation between optic nerve sheath diameter at initial head CT and the Rotterdam CT score. Cureus. 2023; 15(7): e41995.
3. Goswami B, Nanda V, Kataria S, Kataria D. Prediction of in-hospital mortality in patients with traumatic brain injury using the Rotterdam and Marshall CT scores: A retrospective study from western India. Cureus. 2023; 15(7): e41548.
4. Ossipitalia YM. Correlation between serum S100β protein levels and severity of traumatic brain injury as measured by the FOUR score and Rotterdam CT score. Pak J Life Soc Sci. 2024; 22(2).
5. Sekar A, Datta D, Patnaik A. Rotterdam CT score as a predictor of surgical outcome in children with traumatic brain injury. Indian J Pediatr. 2024; 91(1): 90.
6. Wanachiwanawin C, Chatpuwaphat J, Tritrakarn S-O, Chatkaewpaisal A, Tongsai S, Chankaew E, et al. Predictive factors for surgical decision making in nonconcussive traumatic brain injury patients without immediate surgery: a propensity score matching study of optic nerve sheath diameter, Glasgow Coma Scale, and Rotterdam computed tomography score. World Neurosurg. 2024; 193: 936–44.
7. Mahmoodkhani M, Behfarnia P, Aminmansour B. Compare the GCS and the Rotterdam CT score in predicting the mortality and disability of patients with traumatic brain injury. Adv Biomed Res. 2024; 13(1): 35.
8. Coronel Ramos MA. Juan ginés de Sepúlveda obituary written in remembrance of Erasmus of Rotterdam — a memorial or a settling of scores? Philol Canar. 2024; (30 (2024)): 51–73.
9. Manurung JK, Airlangga PS, Hamzah H, Kriswidyatomo P, Sensusiati AD, Utomo B. The relationship between blood levels of ubiquitin carboxyterminal hydrolase L1 (UCH-L1) protein and the severity of traumatic brain injury based on the Glasgow coma scale and Rotterdam CT score. Pharmacogn J. 2024; 16(3): 695–9.
10. Švraka D, Djurdjevic Svraka A, Djajic V, Cucak M, Miskic M. Clinical significance of the control CT Rotterdam score compared with the admission CT Rotterdam score in patients with isolated severe traumatic brain injury in the intensive care unit. Cureus. 2024; 16(9): e69792.
11. Harrison-Felix C, Kolakowsky-Hayner SA, Hammond FM, Wang R, Englander J, Dams-

O'Connor K, et al. Mortality after surviving traumatic brain injury. J Head Trauma Rehabil. 2012; 27(6): E45–56.

12. Osler T, Cook A, Glance LG, Lecky F, Bouamra O, Garrett M, et al. The differential mortality of Glasgow Coma Score in patients with and without head injury. Injury. 2016; 47(9): 1879–85.
13. Chou Y-C, Yeh C-C, Hu C-J, Meng N-H, Chiu W-T, Chou W-H, et al. Risk and mortality of traumatic brain injury in stroke patients: two nationwide cohort studies. J Head Trauma Rehabil. 2014; 29(6): 514–21.
14. Regasa LE, Kaplan DA, Moy Martin EM, Langbein J, Johnson F, Chase LC. Mortality following hospital admission for US active duty service members diagnosed with penetrating traumatic brain injury, 2004-2014. J Head Trauma Rehabil. 2018; 33(2): 123–32.
15. Khokhar B, Simoni-Wastila L, Slejko JF, Perfetto E, Zhan M, Smith GS. Mortality and associated morbidities following traumatic brain injury in older Medicare statin users. J Head Trauma Rehabil. 2018; 33(6): E68–76.
16. O'Neil-Pirozzi TM, Ketchum JM, Hammond FM, Philippus A, Weber E, Dams-O'Connor K. Physical, cognitive, and psychosocial characteristics associated with mortality in chronic TBI survivors: a national institute on disability, independent living, and rehabilitation research traumatic brain injury model systems study. J Head Trauma Rehabil. 2018; 33(4): 237–45.
17. Lystad RP, Cameron CM, Mitchell RJ. Excess mortality among adults hospitalized with traumatic brain injury in Australia: a population-based matched cohort study. J Head Trauma Rehabil. 2019; 34(3): E1–9.
18. Arundon K, Anumas N, Chunthong P, Cheevarungrod A, Phibalsak T, Lim A. Effect of using a head injury fast-track system on reducing the mortality rate among severe head injury patients in Southern Thailand: a retrospective study with historical control. Int J Crit Illn Inj Sci. 2020 Oct; 10(4): 177–81.
19. Gallaher JR, Yohann A, Purcell LN, Kumwenda K-K, Charles A. Trends in head injury associated mortality in Malawi. Injury. 2021; 52(5): 1170–5.
20. Shah G, Joshi C, Prajapati BJ, Gupta NJ. Comparative evaluation of early versus late tracheostomy for reduction of the length of ICU stay, incidence of nosocomial pneumonias, risk of laryngeal injury and mortality of mechanically ventilated patients at a Tertiary Care Hospital in Western India. Indian J Otolaryngol Head Neck Surg. 2022; 74(Suppl 3): 5194–8.