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Original Research Paper

# Acute kidney injury as a prognostic factor in traumatic brain injury: rotterdam score association

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## Abstract
Traumatic brain injury (TBI) is a major cause of disability and mortality worldwide, affecting nearly 50 million people annually. Acute kidney injury (AKI) is a potential complication in critically ill patients, but its relationship with TBI severity remains unclear. This study aimed to assess the association between AKI, Rotterdam score, length of stay (LOS), and outcomes in TBI patients. A cross-sectional study was conducted using medical records of TBI patients admitted to Yogyakarta Islamic Hospital PDHI from 2019 to 2022. Inclusion criteria were age 15–65 years, confirmed TBI diagnosis, head CT scan, and completed hospital treatment. Patients with pre-existing kidney disease, direct renal trauma, shock, or other AKI-related factors were excluded. Rotterdam scores were obtained from radiologist reports. Statistical tests assessed associations between AKI and clinical variables. Seventy-two patients met the criteria; 26.4% developed AKI. Higher Rotterdam scores (4–6) were significantly associated with AKI ($p = 0.026$). No significant association was observed between AKI and LOS ($p = 0.393$). AKI was strongly associated with poor outcomes ($p = 0.004$), with mortality rates of 26.3% in AKI patients compared to 1.9% in non-AKI patients. Higher Rotterdam scores may indicate increased AKI risk in TBI patients, and AKI is associated with markedly worse outcomes. Early recognition and management of kidney injury in high-risk patients may improve survival. Further prospective studies are needed to confirm these findings and explore preventive strategies.

**Keywords:** acute kidney injury; length of stay; outcome; rotterdam score; traumatic brain injury

## 1. Introduction

Traumatic Brain Injury (TBI) includes complex pathological processes. TBI can result in a primary injury that occurs right after the trauma and secondary injuries that cause a number of cellular and molecular reactions that persist for a long time after the trauma, including inflammation, axonal disruption, and damage to neurons and astrocytes. TBI also is one of the leading causes of disability and death worldwide. Every year, almost 50 million people are impacted by TBI. There is still much to learn about the factors that contribute to an individual's vulnerability to developing these conditions.

The Rotterdam CT score is a widely used prognostic tool in the assessment of TBI. Developed to predict mortality and unfavorable outcomes in patients with moderate to severe TBI, this scoring system utilizes computed tomography (CT) imaging findings to stratify patients based on their risk. The Rotterdam CT score evaluates key features such as basal cistern compression, midline shift, epidural mass lesions, and the presence of intraventricular or subarachnoid hemorrhage. By assigning numerical values to these radiological findings, clinicians can quickly assess the severity of brain injury and make informed decisions regarding patient management and potential interventions (Charry et al., 2017). The score's simplicity and reliability have contributed to its widespread adoption in emergency departments and neurosurgical units worldwide, aiding in the early identification of high-risk patients and facilitating timely, appropriate care.

Patiens with multiple trauma, including TBI, frequently have acute kidney damage (AKI), which is linked to higher mortality and longer hospital stays (Robba et al., 2021). Although it may be helpful in identifying people who are at risk, predicting the development of AKI is difficult. AKI in neurocritically ill patients has a complicated and multiple pathogenesis. One of the main factors influencing the development of AKI is the severity of a brain injury, and AKI can exacerbate brain injury, creating a vicious cycle (Barea-Mendoza et al., 2022). A significant part of its development is influenced by the neuroendocrine pathway, which includes the endocrine and central nervous systems as well as the inflammatory and immunological responses. There are several independent risk factors for AKI, including as the ISS (Injury Severity Score), prehospital hemodynamic parameters, renal trauma, blood lactate levels, and the degree of rhabdomyolysis (Robba et al., 2021).

A 2023 prospective observational study of 98 severely injured trauma patients (relevant to TBI settings) found admission levels of neutrophil gelatinase-associated lipocalin (NGAL), high-mobility group box 1 (HMGB-1), creatinine, and myoglobin were significantly higher in those who developed AKI within 7 days, suggesting their value as early indicators in critical care and potential translation to neurotrauma contexts (Freelich *et al,* 2024). Although not yet TBI-specific, these markers reflect emerging paths for timely renal risk stratification in TBI patients, warranting future targeted research.

This study is among the few to directly examine the association between Rotterdam score, a CT-based measure of TBI severity, and the occurrence of acute kidney injury. In contrast to earlier studies that frequently included mixed critical care populations or just examined AKI incidence and death, our investigation evaluated clinical outcomes and hospital length of stay, provided region-specific data from Indonesia, and targeted a homogeneous TBI group. These findings offer new insights into how neuroimaging severity correlates with renal complications, highlighting the potential role of early renal monitoring in severe TBI management. In this paper, we evaluate the relationship of AKI incidence in TBI patients with Rotterdam score, Length of Stay (LOS) and outcome.

## 2. Research Methods

This study is cross-sectional design with descriptive analysis. The sample of this research was patient's medical records. Determination of sample size in this study uses the Slovin formula. The subject of the study was TBI patients which admitted to the hospital from 2019 to 2022 in Yogyakarta Islamic Hospital PDHI. Data were collected from medical records and head CT scan expertise by radiologists. The diagnostic criteria for AKI and the Rotterdam score were adjusted as described in the paragraph below. Inclusion criteria for subjects were ages ranging from 15 – 65, patients which were diagnosed TBI, performed head CT scan, and treated completely in the hospital. Exclusion criteria were history of any kidney disease history, presence of direct trauma to the kidney, presence of shock and any factors related to AKI.

Baseline characteristics such as demographics, symptoms, glasgow coma scale, Rotterdam score, presence of AKI, and outcome of patients were collected as data for this study. The creatinine data and urine output data were used to determine the presence of AKI. The diagnosis of AKI is based on the RIFLE (Risk, Injury, Failure, Loss of kidney function, and End-stage kidney disease) classification, namely if serum creatinine increases two times or urine output is less than 0.5 ml/kg/hour in 12 hours (Lopes & Jorge, 2013).

Rotterdam score was measured based on the patient's head CT scan imaging. The aspects which are evaluated in Rotterdam score are the basal cisterns state, the midline shift size, the presence of epidural lesion and the presence of IVH (Intraventricular haemorrhage) or SAH (Subarachnoid haemorrhage). Patient outcomes are assessed using the criteria that if the patient survives then the outcome is good, but if the patient is deceased then the outcome is poor (Maas et al., 2005).

The independent variable in this study was the incidence of acute kidney injury. The dependent variables measured in this study were the Rotterdam score, LOS, and patient outcomes. The relationship between variables in this study was analyzed using the Fisher exact test, as it did not meet the chi-square criterias.

## 3. Results and Discussion

### 3.1.Characteristic of Subjects

A total of 72 subjects of TBI patients were included in this study. The mean age of all patients is 45,88 year, with standard deviation 20,90 year. Based on gender, there were 49 male patients and 23 female patients. The male patients were more than female patients. The severity of TBI patient was defined according to the GCS of the patients. From all subjects, there were 70,8% mild TBI patients, 18,1% moderate TBI patients and 11,1% severe TBI patients. The incidence of acute kidney injury in patients was 26,4%. Most of the patients had rotterdam score result 1 and 2, with percentage 51,4% and 29,2% respectively. Length of stay of all the patients was approximately 4,74 days, with standard deviation 3,89 days. The total mortality in this study was 8,3% of all subjects. Table 1 shows the characteristic of subjects.

In developing countries, traumatic brain injury continues to be a leading cause of mortality and disability among young people. Based on age, persons over 65 and teenagers between the ages of 15 and 19 are the most likely to have a traumatic brain injury. According to our research, the average age of the patients was 45,88 years old. Another study by Rosyidi et al. (2019) result that the mean age was 31,66 years old (Rosyidi et al., 2019). According to this study, men experienced TBI at a higher rate than women. In the total adult population, epidemiological data also indicate that men are 40% more likely than women to suffer a traumatic brain injury (TBI). This implies that young male adults who work or engage in outdoor activities are more likely to sustain a traumatic brain injury (TBI) (Gupte et al., 2019). According to estimates from the World Health Organisation (WHO), between 70% and 90% of traumatic brain injuries (TBIs) are mild. An estimated 4 million injuries worldwide are attributed to mild TBIs or concussions each year. This finding was consistent with the previous sample.

**Table 1.** Subjects Characteristic

| Characteristics | Subjects | |
|---|---|---|
| | n = 72 | % |
| Age (years) | 45,88 + 20,90 | |
| Gender | | |
| Male | 49 | 68.1 |
| Female | 23 | 31.9 |
| TBI severity (GCS) | | |
| Mild (14 – 15) | 51 | 70.8 |
| Moderate (9 – 13) | 13 | 18.1 |
| Severe (3 – 8) | 8 | 11.1 |
| AKI | | |
| Yes | 19 | 26.4 |
| No | 53 | 73.6 |
| Rotterdam score | 1,82 + 1,08 | |
| 1 | 37 | 51.4 |
| 2 | 21 | 29.2 |
| 3 | 6 | 8.3 |
| 4 | 6 | 8.3 |
| 5 | 2 | 2.8 |

| Characteristics | Subjects | |
|---|---|---|
| | n = 72 | % |
| 6 | 0 | 0 |
| LOS | 4,74 + 3,89 | |
| < 7 days | 57 | 79.2 |
| > 7 days | 15 | 20,8 |
| Outcome | | |
| Survive | 66 | 91.7 |
| Death | 6 | 8.3 |

Acute kidney injury (AKI) is one of complication which can occur in TBI patients. AKI occurs 9.2% to 24% of TBI patients. A Few research have looked on the specifics of AKI stage and duration and how they relate to death in individuals with traumatic brain injury. It is worthwhile to investigate the combined or cumulative impact of AKI stage and duration on the prognosis of TBI patients. In one study, the authors created a brand-new metric called the AKI burden to show a particular critically sick patient's AKI stage as well as duration (Wang et al., 2021).

The pathophysiology of AKI in TBI is complex and multifactorial, involving both direct and indirect mechanisms. The inflammatory plays a crucial role, triggering programmed cell death pathways and upregulating inflammatory cytokines and transcription factors (Cáceres et al., 2024). This inflammatory cascade can lead to systemic effects, potentially impacting kidney function. Additionally, TBI can cause complex metabolic disruptions, affecting systemic metabolism and potentially contributing to AKI development (Posti et al., 2022). One of the primary factors contributing to AKI in TBI patients is the disruption of cerebral autoregulation, which can lead to alterations in systemic hemodynamics and renal perfusion (De Vlieger & Meyfroidt, 2022). The management of intracranial pressure (ICP) and cerebral perfusion pressure (CPP) often involves the use of osmolar agents like mannitol and hypertonic saline, which have been associated with an increased risk of AKI. Furthermore, the use of vasopressors to maintain cerebral perfusion pressure may affect renal perfusion, while fluid resuscitation with saline-based solutions can lead to hyperchloremia, potentially jeopardizing kidney function (De Vlieger & Meyfroidt, 2022).

The pathophysiology of AKI in TBI patients is multifaceted, involving systemic inflammation, metabolic disturbances, and treatment-related factors. Understanding these mechanisms is crucial for developing strategies to prevent and manage AKI in TBI patients, ultimately improving outcomes in this critically ill population (De Vlieger & Meyfroidt, 2022).

There are multiple factors that influence the length of stay (LOS) of TBI patients. The TBI severity and renal disorders involvement are included as factors which prolonged the LOS. The findings in this study are slightly different from a study conducted by Taylor et al. (2024) showed that the mean LOS during the index hospitalization for TBI patients were 7.9 days (SD = 15.7) (Taylor et al., 2024). The total subjects with bad outcome reached 8,3%. The results of this research have a lower mortality rate compared to research conducted in also Indonesia which the mortality rate reached 15,8% (Rosyidi et al., 2019).

## 3.2.Relationship between AKI and Rotterdam Score

**Table 2.** Analysis Result of Variables

| Variable | AKI | | |
|---|---|---|---|
| | Present | Absent | *p-value* |
| Rotterdam Score | | | |
| 1 – 3 | 14 | 50 | 0,026* |
| 4 – 6 | 5 | 3 | |
| Length of stay (LOS) | | | 0,393* |

| Variable | AKI | | *p-value* |
|---|---|---|---|
| | Present | Absent | |
| < 7 days | 16 | 41 | |
| > 7 days | 3 | 12 | |
| Outcome | | | |
| Survive | 14 | 52 | 0,004* |
| Death | 5 | 1 | |

*: Fisher's Exact Test

A statistically significant association (p = 0.026) was observed between Rotterdam Scores and the occurrence of AKI. Patients with higher Rotterdam Scores (4-6) were more likely to develop AKI compared to those with lower scores (1-3). This suggests that the severity of traumatic brain injury (TBI), as indicated by the Rotterdam Score, may be a risk factor for developing AKI. Currently, the previous study which discuss the relationship between AKI and rotterdam score is not found yet. In various clinical scenarios, they do not provide information specifically about the relationship between AKI and the Rotterdam CT score. Further research would be needed to investigate any potential association between these two factors.

However, this finding should be interpreted with caution due to potential sources of bias. Survivor bias is also possible, as patients who died shortly after admission might not have been diagnosed with AKI, leading to underestimation in the most severe group. Information bias could arise from misclassification of AKI due to incomplete or inconsistent serum creatinine and urine output data, as well as inter-observer variability in Rotterdam score interpretation (Maas et al., 2005). Residual confounding is another concern, as unmeasured variables such as hypotension, nephrotoxic medication use, and systemic inflammatory responses may independently increase the risk of both high Rotterdam scores and AKI (Kellum et al., 2021). Furthermore, the retrospective, single-center design limits generalizability, and incomplete medical records may have contributed to recording bias. These factors highlight the need for prospective, multicenter studies with standardized assessments to confirm the observed relationship.

### 3.3.Relationship between AKI and LOS

The relationship between LOS and AKI was not statistically significant (p = 0.393). While a higher proportion of patients with AKI had a LOS < 7 days (16 out of 19) compared to those without AKI (41 out of 53), this difference did not reach statistical significance (table 2). This suggests that the presence of AKI may not significantly impact the duration of hospital stay for TBI patients in this cohort. From previous study conducted by Barrea-Mendoza *et al* (2022), showed that TBI patients who developed AKI had a longer LOS with signifinact statistically. The occurrence of AKI is associated with increased ICU length of stay in TBI patients. This relationship between AKI and prolonged hospital stay is further supported by other studies on trauma patients in general, not specific to TBI (Chen et al., 2024).

Interestingly, the timing of AKI onset may impact outcomes differently. One study found that persistent AKI (lasting >48 hours) was associated with longer mechanical ventilation duration, though it did not find a significant association with overall hospital length of stay in multivariable analysis (Gist et al., 2021). This suggests the need for more research on how the duration and timing of AKI may differentially impact outcomes in TBI patients.The evidence consistently shows an association between AKI and increased length of stay in TBI patients, the exact nature of this relationship may depend on factors like AKI severity, timing, and persistence. Further large-scale studies specifically examining different AKI phenotypes in TBI patients could help clarify these relationships and inform clinical management strategies to potentially reduce hospital stays (Yue et al., 2022).

### 3.4.Relationship between AKI and Patients's Outcome

A highly significant association (p = 0.004) was found between patient outcomes and the presence of AKI. Among patients who developed AKI, 5 out of 19 (26.3%) had poor outcomes (death), compared to only 1 out of 53 (1.9%) patients without AKI. This indicates that AKI is strongly associated with increased mortality in TBI patients. Wang et al. (2024) conducted study which showed result that the overall mortality of TBI patients who developed AKI was 44.7%. The AKI group had a significantly higher in-hospital mortality rate than the non-AKI group (p <0.001).

The occurrence of AKI is associated with increased mortality and extended hospital length of stay in TBI patients (Robba et al., 2020). Multiple studies have found that AKI is an independent risk factor for poor outcomes and mortality in TBI patients (Robba et al., 2020; Wang et al., 2024). Previous studies have consistently shown a significant relationship between acute kidney injury (AKI) and outcomes in patients with traumatic brain injury (TBI): AKI is prevalent in hospitalized TBI patients, with incidence rates ranging from 10.4% to 19.8% (Wang et al., 2021; Wang et al., 2024).

Interestingly, the timing and severity of AKI appear to be important factors. AKI typically occurs early after ICU admission, with a median of 2 days post-admission (Robba et al., 2020). The highest AKI stage reached is significantly associated with mortality, while AKI duration and burden are not (Wang et al., 2021). This suggests that the severity of kidney injury, rather than its persistence, may be more predictive of outcomes.

## 4. Conclusion

In conclusion, the significant association between higher Rotterdam Scores and AKI suggests that more severe brain injuries may lead to a higher risk of kidney dysfunction. This could be due to various factors such as hemodynamic instability, inflammatory responses, or the use of nephrotoxic medications in managing severe TBI cases. The strong relationship between AKI and poor outcomes underscores the importance of early detection and management of kidney injury in TBI patients. It suggests that AKI may be an important prognostic factor in TBI and that preventing or effectively treating AKI could potentially improve survival rates. While the LOS was not significantly associated with AKI in this study, further research with larger sample sizes may be needed to fully elucidate this relationship. Factors such as the severity of AKI, timing of onset, and specific management strategies could influence LOS and should be considered in future studies.

These results emphasize the need for vigilant monitoring of renal function in TBI patients, particularly those with high Rotterdam Scores. Implementing renal protective strategies and early interventions for AKI in TBI management protocols could potentially improve patient outcomes and reduce mortality rates.

The contribution of this study lies in identifying AKI as a predictor of prognosis and mortality in TBI patients. For clinicians, this means that patients with signs of AKI should be prioritized for observation due to their higher prognosis and risk of mortality. For hospital systems, integrating AKI risk assessment into TBI management protocols can improve prognosis, reduce complications, and potentially decrease mortality. For communities, especially in resource-limited settings, implementing these targeted prevention strategies can reduce the burden of disability and death from TBI-related complications.

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