

Age and Type of Hemorrhage as Factors Associated with Mortality in Patients with Traffic Accident-Related Head Injuries

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ABSTRACT

Background: Road traffic accidents remain a significant global health problem and are among the leading causes of trauma-related mortality, particularly in developing countries. Head injury is one of the most serious consequences of road traffic accidents and contributes substantially to death and disability. Several factors, including age, sex, and type of intracranial haemorrhage, have been reported to affect mortality among patients with head injuries; however, studies in Indonesia have generally examined these factors separately. Evidence regarding the simultaneous relationship of these variables with mortality remains limited. Therefore, this study aimed to analyze the relationship between age, sex, and type of haemorrhage and mortality in patients with head injuries following road traffic accidents.

Subjects and Method: This cross-sectional study included 1,355 patients with head injuries due to road traffic accidents treated at Rumah Sakit Umum Daerah dr. Moewardi, Surakarta. Data on mortality, age, sex, and type of hemorrhage were collected from medical records (January 2023–January 2026) and analyzed using multiple logistic regression.

Results: Older adults had a significantly higher risk of mortality than adults (OR= 2.03; 95% CI= 1.66 to 2.47; $p<0.05$). No significant association was found between sex and mortality ($p>0.05$). Mortality was significantly associated with the type of hemorrhage ($p<0.05$), with subdural hemorrhage showing the highest mortality rate (26.5%). Multivariate analysis demonstrated that age (aOR= 2.34; 95% CI= 1.77 to 3.08; $p<0.05$) and type of hemorrhage (aOR= 1.44; 95% CI= 1.22 to 1.71; $p<0.05$) were independent predictors of mortality, with age contributing more strongly to the model.

Conclusion: Advanced age and subdural haemorrhage significantly associated with increased mortality in patients with head injuries following road traffic accidents, whilst gender was not found to be a significant factor.

Keywords: Age, gender, cerebral haemorrhage, mortality, traumatic head injury.

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BACKGROUND

Traffic accidents are a major public health concern and represent a negative consequence of the rapid growth in transporta-

tion mobility. They are currently among the ten leading causes of death worldwide, ranking ninth globally, and are projected to become the seventh leading cause of death

by 2030 (Tanan et al., 2025). Data from the Indonesian National Police Traffic Corps indicate that road traffic accidents remain a substantial public health and socio-economic problem in Indonesia. In 2022, 94,671 traffic accident cases were recorded, resulting in 19,054 deaths. National police statistics further reported 131,500 traffic accidents in the same year, approximately 74.35% of which involved motorcycles (Rusman et al., 2025).

Head injury is one of the most serious consequences of traffic accidents, accounting for approximately 50% of trauma cases related to road traffic incidents. The global incidence of head injury is estimated to range from 56 to 430 cases per 100,000 population annually (Tanan et al., 2025). The severity of head injuries varies widely, from mild concussions to severe traumatic brain injuries that can threaten life and significantly impair neurological function. Clinical outcomes also vary considerably, ranging from complete recovery to permanent disability or death. Mortality may occur within the first 24 hours due to extensive primary brain injury or after 24 hours as a result of secondary complications, including ongoing hemorrhage, cerebral edema, and infection (Mudzakir & Susanti, 2020).

Based on previous studies, several factors have been associated with mortality from head injuries resulting from traffic accidents. Advanced age is associated with poorer outcomes due to changes in physiological conditions and comorbidities. The aging process leads to a decrease in brain parenchymal volume, a 40–60% impairment in cerebral blood flow autoregulation, and increased susceptibility to intracranial hemorrhage. Meanwhile, the location of intracranial hemorrhage has different prognostic implications, with acute subdural hemorrhage being significantly associated

with poor functional outcomes. Several studies have reported that sex is associated with differing risks, although the results remain inconsistent. Research by Igbokwe et al. (2021) revealed that women are 1.22 times more likely to experience poor outcomes following head injury, a finding thought to be linked to hormonal neuro-protective mechanisms. Meanwhile, the location of intracranial haemorrhage has different prognostic implications. The interaction between age, sex and the location of the haemorrhage in influencing head injury outcomes is complex. Male patients of working age (20–40 years) are more prone to severe head injuries with multiple haemorrhages resulting from high-speed accidents (Dunne et al., 2020).

Most studies in Indonesia still address these factors separately; thus, the simultaneous correlation between age, sex, and hemorrhage location on mortality in patients with head injuries has not been comprehensively examined, particularly among patients with a history of traffic accidents treated at regional referral hospitals.

Based on the above, the research questions in this study are: (1) Is there a relationship between age and mortality in patients with head injuries following traffic accidents? (2) Is there a relationship between sex and mortality in patients with head injuries following traffic accidents? (3) Is there a relationship between the type of haemorrhage and mortality in patients with head injuries following traffic accidents? (4) Is there a relationship between age, sex, and type of haemorrhage, considered simultaneously, and mortality in patients with head injuries following traffic accidents?

This study aims to analyze the relationship between age, sex, and type of haemorrhage on mortality in patients with

head injuries following traffic accidents at dr. Moewardi Hospital, Surakarta, Central Java, Indonesia.

SUBJECTS AND METHOD

1. Study Design

This study employed an analytical observational method using a cross-sectional approach. Analytical observational research is designed to examine the relationship between two or more variables through observation without any intervention administered to the study subjects. A cross-sectional design involves conducting measurements or observations of the study subjects at a single point in time, allowing the assessment of variables simultaneously within one observation period. However, because this study relied on retrospective medical record data, some potentially important confounding variables may not have been available or consistently documented, which could have influenced the observed associations.

2. Population and Sample

This study was conducted at dr. Moewardi Hospital, Surakarta Central Java, Indonesia, from January 2026 to May 2026. The target population consisted of all patients with post-traffic accident traumatic brain injury recorded in the hospital medical records during the period of 2023–2025. The accessible population included patients who fulfilled the predetermined eligibility criteria.

The study sample comprised patients with post-traffic accident traumatic brain injury who met the eligibility criteria and were identified from the hospital medical records database. Sampling was performed using a purposive sampling technique, a non-probability sampling method in which participants are intentionally selected based on characteristics relevant to the objectives of the study. The minimum required

sample size was calculated using the Lemeshow formula, resulting in a minimum sample of 161 cases. A total of 1,355 eligible patients met the study criteria and were included in the analysis.

3. Study Variables

The independent variables in this study were age, sex, and type of intracranial hemorrhage. Age was categorized into adults (18–60 years) and elderly (>60 years). Sex was classified as male and female. The type of intracranial hemorrhage was determined based on head CT scan findings and categorized into epidural hemorrhage, subdural hemorrhage, subarachnoid hemorrhage, and intracerebral hemorrhage. The dependent variable was patient mortality, categorized as survived or deceased.

4. Operational Definition of Variables

Age was defined as the patient's age recorded in the medical records at the time of hospital admission and categorized into adults (18–60 years) and elderly (>60 years). Sex was defined as the biological sex documented in the medical records and classified as male or female.

The type of intracranial hemorrhage was determined based on head computed tomography scan findings and radiological records and categorized into epidural hemorrhage, subdural hemorrhage, subarachnoid hemorrhage, and intracerebral hemorrhage.

Patient mortality was defined as the final clinical outcome documented in the medical records during hospitalization and categorized as survived or deceased.

5. Study Instruments

Data of patient medical records were obtained from dr. Moewardi Hospital. The medical records included data from patients diagnosed with traumatic brain injury following traffic accidents during the study period. Data extracted from the

records included demographic characteristics, head computed tomography scan findings with radiological documentation of intracranial hemorrhage location, and patient mortality outcomes.

6. Data analysis

Data analysis comprised univariate analysis to describe study variables, followed by bivariate analysis using the Chi-square test to assess associations with mortality. Multivariate logistic regression was then performed to identify factors independently associated with mortality.

7. Research Ethics

Ethical approval for this study was obtained from the Health Research Ethics Committee of Dr. Moewardi Hospital, Surakarta, Central Java, Indonesia (Approval

No. 2.688/XII/HREC/2025), on January 7, 2026.

RESULTS

1. Sample Characteristics

This study used secondary data obtained from the medical records of patients with traumatic brain injury caused by traffic accidents at Rumah Sakit Umum Daerah dr. Moewardi, Surakarta, from January 2023 to January 2026. A total of 1,355 patients were included and categorized according to mortality outcome into deceased and surviving groups. The characteristics of the study subjects are presented in Table 1.

Table 1. Characteristics of the study subject

Variables	Frequency	%
Age		
Adults	997	73.6
Older adults	358	26.4
Sex		
Male	960	70.8
Female	395	29.2
Type of Hemorrhage		
Epidural	286	21.1
Subdural	807	59.6
Subarachnoid	81	6.0
Intracerebral	181	13.4
Mortality		
Alive	1,063	78.5
Die	292	21.5

Based on Table 1, the majority of patients were adults aged 18–60 years, comprising 997 patients (73.6%), while 358 patients (26.4%) were elderly (>60 years). Male patients predominated, accounting for 960 patients (70.8%), compared with 395 female patients (29.2%). Regarding the type of intracranial hemorrhage, subdural hemorrhage was the most common type, occurring in 807 patients (59.6%), followed by epidural hemorrhage in 286 patients

(21.1%), intracerebral hemorrhage in 181 patients (13.4%), and subarachnoid hemorrhage in 81 patients (6.0%). Overall, 1,063 patients (78.5%) survived, whereas 292 patients (21.5%) died.

2. Bivariate Analysis

a. Association between sex and mortality

As shown in Table 2, mortality occurred in 168 adult patients (16.9%) and 124 elderly patients (34.6%). Conversely, 829 adults

(83.1%) and 234 elderly patients (65.4%) survived.

A statistically significant association was observed between age and mortality ($p < 0.001$). The odds ratio for adults compared with elderly patients was 0.49

(95% CI: 0.40–0.59), indicating that adults had lower odds of mortality than elderly patients. Equivalently, elderly patients had approximately 2.04 times higher odds of mortality than adults.

Table 2. Bivariate Analysis between Age and Mortality

Variables	Mortality				OR (95%CI)	p
	Die		Alive			
	n	%	n	%		
Adults	168	16.9	829	83.1	0.49 (0.40 - 0.59)	<0.001
Older adults	124	34.6	234	65.4		

b. Association between sex and mortality

Among male patients, 213 (22.2%) died and 747 (77.8%) survived. Among female patients, 79 (20.0%) died and 316 (80.0%) survived. The analysis showed no statis-

tically significant association between sex and mortality ($p = 0.414$). The odds ratio was 1.11 (95% CI: 0.88–1.40), indicating that the odds of mortality were not significantly different between male and female patients.

Table 3. Bivariate Analysis between Sex and Mortality

Variables	Mortality				OR (95%CI)	p
	Die		Alive			
	n	%	n	%		
Sex						
Male	213	22.2	747	77.8	1.11 (0.88 - 1.40)	0.414
Female	79	20	316	80		

a. Association between Type of Intracranial Hemorrhage and Mortality

The association between the type of intracranial hemorrhage and mortality was analyzed using the Chi-square test. Among patients with subdural hemorrhage, 214 (26.5%) died and 593 (73.5%) survived. Among patients with non-subdural hemorrhage, 78 (14.2%) died and 470 (85.8%) survived.

There was a statistically significant association between subdural hemorrhage and mortality ($p < 0.001$). Patients with subdural hemorrhage had 2.20 times

higher odds of mortality than those with non-subdural hemorrhage (OR=2.20; 95% CI= 1.63 to 2.90).

Pairwise comparisons among the different types of intracranial hemorrhage are presented in Table 5. The comparison between subdural and epidural hemorrhage showed a statistically significant association ($p = 0.001$), with subdural hemorrhage associated with higher odds of mortality (OR= 1.84; 95%CI= 1.29 to 2.60). A significant association was also observed between subdural and intracerebral hemorrhage (OR=2.91; 95%CI=1.78 to 4.74; $p < 0.001$).

Table 4. Bivariate Analysis between Type of Intracranial Hemorrhage and Mortality

Variables	Mortality status		OR (95% CI)	p
	Died n (%)	Alive n (%)		
Type of hemorrhage				
Subdural	214 (26.5)	593 (73.5)	2.20 (1.63–2.90)	<0.001
Non-subdural	78 (14.2)	470 (85.8)	Ref.	

Based on Table 5, the comparison between subdural and epidural hemorrhage showed a statistically significant association (OR=1.84; 95%CI= 1.29 to 2.60; p=0.001). The comparison between subdural and subarachnoid hemorrhage was also statistically significant (OR=2.30; 95%CI= 1.19 to 4.42; p=0.016). Similarly, the comparison between subdural and intracerebral hemorrhage showed a statistically signi-

ficant association (OR=2.91; 95%CI= 1.78 to 4.74; p<0.001). In contrast, no statistically significant associations were observed in the comparisons between epidural and subarachnoid hemorrhage (OR=1.25; 95%CI= 0.62 to 2.54; p=0.653), epidural and intracerebral hemorrhage (OR=1.58; 95% CI= 0.90 to 2.77; p=0.138), or intracerebral and subarachnoid hemorrhage (OR=0.79; 95%CI= 0.36 to 1.74; p=0.705).

Table 5. Comparison of Intracranial Hemorrhage types with mortality

Type of hemorrhage	OR (95% CI)	p
Subdural	Ref.	
Epidural	1.84 (1.29–2.60)	0.001
Subarachnoid	2.30 (1.19–4.42)	0.016
Intracerebral	2.91 (1.78–4.74)	<0.001
Epidural	Ref.	
Subarachnoid	1.25 (0.62–2.54)	0.653
Intracerebral	1.58 (0.90–2.77)	0.138
Intracerebral	Ref.	
Subarachnoid	0.79 (0.36–1.74)	0.705

3. Multivariate Analysis

Table 6 showed that age was significantly associated with mortality, with a regression coefficient of B=0.85 and an OR of 2.34

(95%CI= 1.77 to 3.09; p<0.001). Type of hemorrhage was also significantly associated with mortality (OR= 1.44; 95%CI= 1.22 to 1.71; p<0.001).

Table 6. Multivariate Logistic Regression Analysis

Variables	OR	95% CI	p
Age (older adults)	2.34	1.77 - 3.09	<0.001
Type of Hemorrhage	1.44	1.22 - 1.71	<0.001

DISCUSSION

1. Association between Age and Mortality.

The findings of this study demonstrated a significant association between age and mortality among patients with traumatic

brain injury following traffic accidents (p<0.001). Elderly patients (>60 years) had a 2.03-fold higher risk of mortality compared with adult patients aged 18–60 years. These findings are consistent with the study conducted by Paget et al. (2021),

which reported that mortality among patients with traumatic brain injury increased progressively with age, ranging from 15% in the 15–24-year age group to 71% among patients aged 85 years and older. Similarly, Jochems et al. (2021) and Rau et al. (2019) found that older patients with moderate to severe traumatic brain injury experienced higher mortality rates compared with younger age groups.

The increased mortality risk observed in older patients may be explained by several physiological mechanisms. Aging is associated with reduced cerebral reserve and decreased neuroplasticity, resulting in diminished capacity of the brain to compensate for traumatic injury. In addition, older patients frequently present with comorbid conditions such as hypertension, diabetes mellitus, and cardiovascular disease, which may contribute to poorer clinical outcomes following traumatic brain injury (Mattingly & Roth, 2022). Gardner et al. (2018) further suggested that even mild traumatic brain injury in geriatric populations may lead to substantial clinical deterioration due to decreased physiological reserve and increased susceptibility to secondary injury mechanisms, including cerebral edema and progressive intracranial hemorrhage.

Additional evidence from Rahman et al. (2022) supports that traumatic brain injury is a strong predictor of mortality among older trauma patients, particularly after the first 48 hours of hospitalization. Furthermore, a meta-analysis which included 23 studies, reported mortality rates ranging from 50% to 80% among Elderly with severe traumatic brain injury, depending on injury severity and accompanying comorbidities. Therefore, the findings of the present study reinforce existing evidence that advanced age is one of the most consistent independent risk

factors associated with poor outcomes and increased mortality in patients with traumatic brain injury.

2. Association between Sex and Mortality.

In this study, no statistically significant association was found between sex and mortality among patients with traumatic brain injury following traffic accidents ($p=0.414$). Nevertheless, male patients demonstrated a 1.11-fold higher relative risk of mortality compared with female patients. These findings are consistent with previous studies indicating that males are at greater risk of sustaining traumatic brain injury. Nugroho & Masrika (2025) reported that the majority of patients with traumatic brain injury caused by motor vehicle accidents were male (64.8%). However, their study emphasized Glasgow Coma Scale (GCS) scores and injury-to-admission time as stronger predictors of mortality than sex.

The difference in traumatic brain injury incidence between males and females is largely attributed to behavioral and exposure-related factors rather than biological differences alone. Dunne et al. (2020), in their epidemiological study, reported that males in the productive age group (20–40 years) were more likely to experience severe traumatic brain injury with multiple intracranial hemorrhages due to high-speed traffic accidents, including behaviors such as riding motorcycles without helmets and engaging in more aggressive driving patterns.

Evidence from the Global Burden of Road Injuries study by Gu et al. (2025) also demonstrated that the highest incidence of road traffic injuries occurred among individuals aged 25–29 years and was predominantly observed in males, resulting in a greater injury burden in this population. However, once patients receive

hospital treatment, factors directly related to injury severity appear to play a more important role in determining outcomes. Supporting this interpretation, Rosen et al. (2025) and Igbokwe et al. (2021) found that injury severity, Glasgow Coma Scale (GCS), and hypotension during hospitalization were more strongly associated with mortality than sex. Therefore, the findings of the present study, which demonstrated no significant association between sex and mortality, are consistent with current evidence suggesting that sex is not an independent predictor of traumatic brain injury outcomes after controlling for other factors such as age and injury severity.

3. Association between Type of Intracranial Hemorrhage and Mortality.

The present study demonstrated a significant association between intracranial hemorrhage type and mortality among patients with traffic accident-related head injuries. Subdural hemorrhage showed the highest mortality rate (26.5%), followed by epidural hemorrhage (16.4%), subarachnoid hemorrhage (13.6%), and intracerebral hemorrhage (11.0%). Patients with subdural hemorrhage had 2.2-fold higher odds of mortality than those with non-subdural hemorrhage. These findings are consistent with previous studies identifying subdural hemorrhage as a major determinant of in-hospital mortality among patients with traumatic brain injury (Paget et al., 2021; Vazquez et al., 2024).

The predominance and high mortality of subdural hemorrhage may be explained by its underlying injury mechanism. Traffic accidents commonly involve acceleration–deceleration forces that cause tearing of the bridging veins between the cerebral cortex and dural venous sinuses, leading to subdural blood accumulation. In addition to producing a substantial mass effect,

subdural hemorrhage is frequently accompanied by diffuse parenchymal injury, elevated intracranial pressure, and an increased risk of cerebral herniation, all of which contribute to poorer outcomes (Pruitt, 2022; Mo & Ee, 2023). Similar findings have been reported in Indonesia, where patients undergoing surgery for acute subdural hemorrhage continued to experience considerable in-hospital mortality (Irwansyah et al., 2025).

Pairwise comparisons further demonstrated that subdural hemorrhage was associated with significantly higher mortality than epidural hemorrhage, intracerebral hemorrhage, and subarachnoid hemorrhage. The lower mortality observed in epidural hemorrhage may be attributable to its extra-axial location and the effectiveness of early surgical evacuation, which often results in favorable neurological recovery when treatment is not delayed (Khairat et al., 2025; David, 2025).

Although intracerebral hemorrhage is generally considered a severe injury because of its intra-axial location, its mortality rate in the present study was lower than that of subdural hemorrhage. This finding may reflect the inclusion of traumatic rather than spontaneous intracerebral hemorrhage, which is often associated with a better prognosis. In addition, patients with extensive hemorrhage involving critical brain structures may have died before hospital admission and were therefore not captured in the study population (Lehtola et al., 2018; Behrndtz et al., 2024).

Similarly, subarachnoid hemorrhage exhibited a lower mortality rate than subdural hemorrhage. Traumatic subarachnoid hemorrhage is frequently self-limiting and may not require surgical intervention, particularly in patients with preserved neurological status. Previous studies have

shown that outcomes vary considerably according to injury severity, associated intracranial lesions, and underlying comorbidities, with isolated traumatic subarachnoid hemorrhage generally demonstrating a favorable prognosis (Griswold et al., 2022; Rau et al., 2019; Kono et al., 2026). No significant differences in mortality were observed among the non-subdural hemorrhage groups, including epidural, intracerebral, and subarachnoid hemorrhage. This finding suggests that the markedly increased mortality associated with subdural hemorrhage may represent the primary driver of the overall association between hemorrhage type and mortality. The prognosis of the remaining hemorrhage types may be more strongly influenced by other clinical factors, such as injury severity, Glasgow Coma Scale score, associated injuries, and pre-existing comorbidities.

4. Independent Predictors of Mortality in Patients with Traumatic Brain Injury Following Traffic Accidents.

The multivariate analysis demonstrated that age and type of intracranial hemorrhage were independently associated with mortality after adjustment for other variables, whereas sex was not significantly associated with mortality. Age showed the strongest association with mortality, followed by hemorrhage type. These findings suggest that both patient characteristics and injury-related factors contribute to mortality among patients with traffic accident-related head injuries.

The significant association between advanced age and mortality is biologically plausible. Aging is accompanied by cerebral atrophy, reduced cerebral reserve, impaired neuroplasticity, and diminished autoregulatory capacity, all of which increase vulnerability to both primary and second-

ary brain injury. Older adults are also more likely to have comorbidities and use antiplatelet or anticoagulant medications, which may worsen intracranial bleeding and clinical outcomes. Previous studies have consistently identified age as one of the most important determinants of mortality and poor outcomes following traumatic brain injury (Gardner et al., 2018; Krueger et al., 2019; Mattingly & Roth, 2022). Consistent with these findings, a systematic review by Astuti and Veibiani (2025) demonstrated that advanced age is a major risk factor for postoperative cognitive dysfunction in elderly surgical patients, further supporting the notion that age-related decline in neuroplasticity and physiological reserve increases susceptibility to neurological insults.

Furthermore, subdural hemorrhage has been reported to occur more frequently among older patients because age-related cerebral atrophy increases tension on bridging veins, making them more susceptible to rupture following trauma (Shpiner et al., 2019).

Hemorrhage type also remained independently associated with mortality after adjustment for age. Different hemorrhage types have distinct pathophysiological characteristics and prognostic implications. Subdural hemorrhage is often associated with extensive mass effect, elevated intracranial pressure, and diffuse brain injury, whereas other hemorrhage types may have different patterns of neurological compromise and responses to treatment. Previous studies have similarly demonstrated that lesion characteristics and hemorrhage location are important determinants of clinical outcomes in traumatic brain injury (Hong et al., 2025; Zhong et al., 2025).

Taken together, the findings indicate that age and hemorrhage type jointly influence mortality among patients with trau-

matic brain injury following road traffic accidents. The stronger regression coefficient observed for age suggests that patient-related factors may have a greater impact on mortality than hemorrhage type alone. These results highlight the importance of considering both demographic characteristics and intracranial injury patterns when evaluating prognosis and managing patients with traffic accident-related head injuries.

AUTHORS CONTRIBUTION

All authors contributed substantially to the study. Author contributions included study conceptualization and design, data collection, data analysis and interpretation, manuscript drafting, critical revision of the manuscript for important intellectual content, and approval of the final version for publication.

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CONFLICT OF INTEREST

The authors declare that the study was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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