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Original Article

The epidemiology of motorcycle-related acute traumatic brain injury: The NOMADEN study

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ABSTRACT

Background: Although persisting to be a public health hazard in Indonesia, motorcycle-related traumatic brain injury (TBI) due to road traffic accidents (RTA) lacks comprehensive national data. We aim to study the epidemiological pattern of motorcycle-related TBI and analyze the determinants related to mortality in the only neurosurgical center in the rural province of North Maluku, Indonesia.

Methods: Using the North Maluku Database in Neurosurgery register, information regarding age, sex, health insurance, alcohol use, point of referral, degree of severity, brain computed tomography abnormalities, helmet use, surgery, injury-to-admission time (IAT), and relationship to the motorcycle were obtained from patients admitted to Chasan Boesoirie General Hospital, Ternate, in 2021–2022. Multivariable logistic regression analysis was performed to investigate associations with in-hospital mortality.

Results: Of all RTA-related TBI patients (n = 353), 91.8% (n = 324) were caused by motorcycle collision (mean age ± standard deviation of 30.5 ± 16.7 years old). The majority were motorcyclists (66.7%), male (64.8%), IAT >4 h (55.9%), financed by non-Jaminan Kesehatan Nasional mechanism (66.4%), not under alcohol influence (78.4%), referred from Ternate (55.2%), and suffered mild TBI (75%). Thirty patients (9.3%) succumbed to death. Moreover, 9.3% and 91.2% were ≤17 years old and helmetless. Glasgow coma scale and IAT were significantly associated with in-hospital mortality (odds ratio [95% confidence interval]: 0.58 [0.49–0.68] and 5.44 [1.00–30.34], respectively).

Conclusion: The young and productive males dominated the motorcycle-related TBI patients in North Maluku. Poor compliance with road traffic laws, as demonstrated by a considerable proportion of underage, alcohol-intoxicated, and helmetless patients, necessitated prompt actions from all related elements.

Keywords: Epidemiology, Motorcycle, Traumatic brain injury, Rural area

INTRODUCTION

Traumatic brain injury (TBI) is defined as an acquired assault to the brain due to external force, ranging from a mild head blow (concussion) to a violent penetrating attack on the skull and brain parenchyma.[10,15] Of all common neurological pathologies, TBI shows the greatest incidence and, as a consequence, prompts a profound effect on global death and disability, particularly in low- and middle-income countries (LMICs).[31] The Global Burden of Disease Study on TBI worldwide discovered that in 2019, there were 27.16 million new cases, 48.99 million prevalent cases, and 7.08 million years lived with disability.[19] In 2018, Dewan *et al.* estimated an annual global TBI incidence of 69 million cases and thrice higher the incidence of TBI in LMICs than

in high-income countries (HIC).[13] One of the causes of this discrepancy in TBI occurrence is the contrasting prevalence of road traffic accidents (RTA) between the two respective country income groups.[19]

In 2021, RTA was estimated to be responsible for 1.19 million injury deaths and the predominant cause of mortality among children and productive generations aged 5–29 years worldwide.[56] It is the primary cause of TBI in LMICs, where 72.3% of global TBI cases occurred and where mortality was three-fold to four-fold higher than in HICs. Although having similar RTA incidence to Europe, Southeast Asia's (SEA) proportion of RTA-related TBIs was strikingly higher (56% vs. 36%), suggesting any issues related to road traffic safety in this region.[13] Moreover, since 60% of SEA countries are categorized as LMICs, their TBI characteristics, management strategy, and outcome differ from HICs.[39] While falls become the most prevalent cause of TBI in the latter, RTA, particularly motorcycle crashes, is the main culprit in the former.[31] Consequently, with the urbanization, industrialization, and easiness in the manner of motorcycle ownership in LMICs, death and disability due to motorcycle-related TBIs are expected to increase in this region without proper laws on vehicle and road safety in place.[11]

As one of the SEA LMICs with a population of ±277 million people, the fourth highest in the world, Indonesia has to tackle the triple burden of communicable diseases, non-communicable diseases, and road injuries.[55] According to the 2018 Indonesia Basic Health Research, TBI was the third most common of all injuries (11.9%), and 72.7% of them were due to motorcycle-related RTA, particularly among the age group 15–24 years old.[24] Regardless of the direness of the situation, only a few associated studies from Indonesia exist. Database search from Scopus-indexed journals generated five TBI-related papers from various regions in Indonesia: four single-center and one multi-center retrospective studies from healthcare facilities spread across the islands of Sumatra, Java, Bali, and Nusa Tenggara/Lesser Sunda.[14,34,41,45,46] No study from North Maluku has ever been commenced.

Considering the importance of sound scientific justification as the basis for future public health decision-making in the region, this study, a follow-up of the North Maluku Database in Neurosurgery (NOMADEN), aims to investigate the epidemiological pattern of motorcycle-related TBI and analyze the demographic determinants that may be related to mortality among TBI patients in this rural province in the eastern part of Indonesia.[36]

MATERIALS AND METHODS

Subjects

The NOMADEN is a single-center and hospital-based registry created to be the database for all neurosurgical cases in North Maluku, an archipelagic region in Indonesia populated by 1.2 million.[36] Demographic and clinical information were prospectively obtained and cross-referenced with logs from the emergency room, outpatient clinic, intensive care unit, wards, and operating theatre. This study centered on 544 TBI patients registered from January 1st, 2021, to December 31st, 2022. After excluding non-acute TBI patients (n = 72), 472 acute cases presented to the emergency department of Chasan Boesorie General Hospital, Ternate, were included in the final analysis. The Institutional Review Board of Universitas Khairun has granted ethical approval for this study. Ethical clearance number: 57/UN27.06.11/KEP/EC/2023

DETERMINATION OF TBI

All diagnoses of TBI were made solely by the neurosurgeon as it is the hospital policy to refer all TBI cases from the emergency department to neurosurgical care. Brain computed tomography (CT) scans were performed according to the Canadian Head CT Rule.[48] The neurosurgeon analyzed all radiological images in the 1st year of service since no radiologist was available then.

Variables and outcome

Information about age, sex, health insurance, suspected alcohol use, point of referral, degree of severity, brain CT abnormalities, helmet use, surgery, mechanism of injury, injury-to-admission time (IAT), vehicle type, and their relationship to the vehicle was obtained. Seventeen was selected as the age cutoff point since this is the minimum age for Indonesians to be legally granted motorcycle driving licenses.[28] Health insurances were dichotomized into the *Jaminan Kesehatan Nasional* (JKN, Indonesia's national health insurance) and non-JKN, including the out-of-pocket mechanism and the special insurance by Jasa Raharja (JR), a state-owned insurance company focusing on organizing RTA fund. Suspicion of alcohol use was ascertained through either interviews with patients (considering they were fully conscious) or their relatives and physical examination (alcohol breath); laboratory confirmation was unattainable due to the unavailability of such a device. The point of referral was divided into Ternate-based and outside Ternate-based. TBI degree of severity was classified as mild (Glasgow coma scale [GCS] 13–15), moderate (GCS 9–12), or severe (GCS 3–8).[29] Brain CT abnormalities comprised vault skull fracture (e.g., linear fracture and depressed fracture), basilar skull fracture, diffuse intracranial lesion (e.g., diffuse axonal injury), focal intracranial lesion (e.g., epidural hematoma, subdural hematoma), and none identified.[51] Types of neurosurgical procedures were craniotomy hematoma evacuation, decompressive craniectomy-hematoma evacuation, debridement, fracture reduction, removal

of foreign material, and cerebrospinal fluid diversion. Mechanisms of injury consisted of RTA and non-RTA (falls, accidental head blows, and violence). IAT was dichotomized into ≤4 h after injury and >4 h since worsening of the TBI outcome, particularly in moderate TBI cases, was documented beyond this period.[6] Vehicle type was divided into motorcycle and car/truck. Patients' relation to the vehicle was defined as motorcyclist, passenger, or pedestrian. The study outcome was in-hospital mortality, defined as any death at any point in hospital care.

Statistical analysis

Initially, all characteristics were described and compared according to the mortality status, followed by a similar analysis of the most prevalent cause of RTA-related TBI. Continuous variables were presented as mean ± standard deviation (SD) or median (Interquartile range [IQR]), and categorical variables as proportions. District-based case distribution, causal mechanism, and IAT were graphically depicted, together with the overall surgical diagnoses and neurosurgical procedures performed. Uni- and multivariable logistic regression analyses were conducted to investigate any significant association between predictors and the study outcome. IBM Statistical Package for the Social Sciences version 25 software was used in all statistical analyses. A two-tailed $P < 0.05$ was determined to be statistically significant.

RESULTS

Overview of acute TBI patients

Figure 1 presents the acute case's distribution, causal mechanism, and median IAT hour (IQR). In all but Taliabu district ($n = 0$), RTA was noted as the top mechanism of injury. Moreover, in all districts except Ternate, the median IAT was predominantly above 4 h. The neurosurgical diagnoses and procedures performed from 2021 to 2022 are shown in Figure 2. Nearly, a third (31.4%) of all operated conditions were traumatic intracerebral hemorrhage, and 42.9% of the surgeries were decompressive craniectomy-hematoma evacuation.

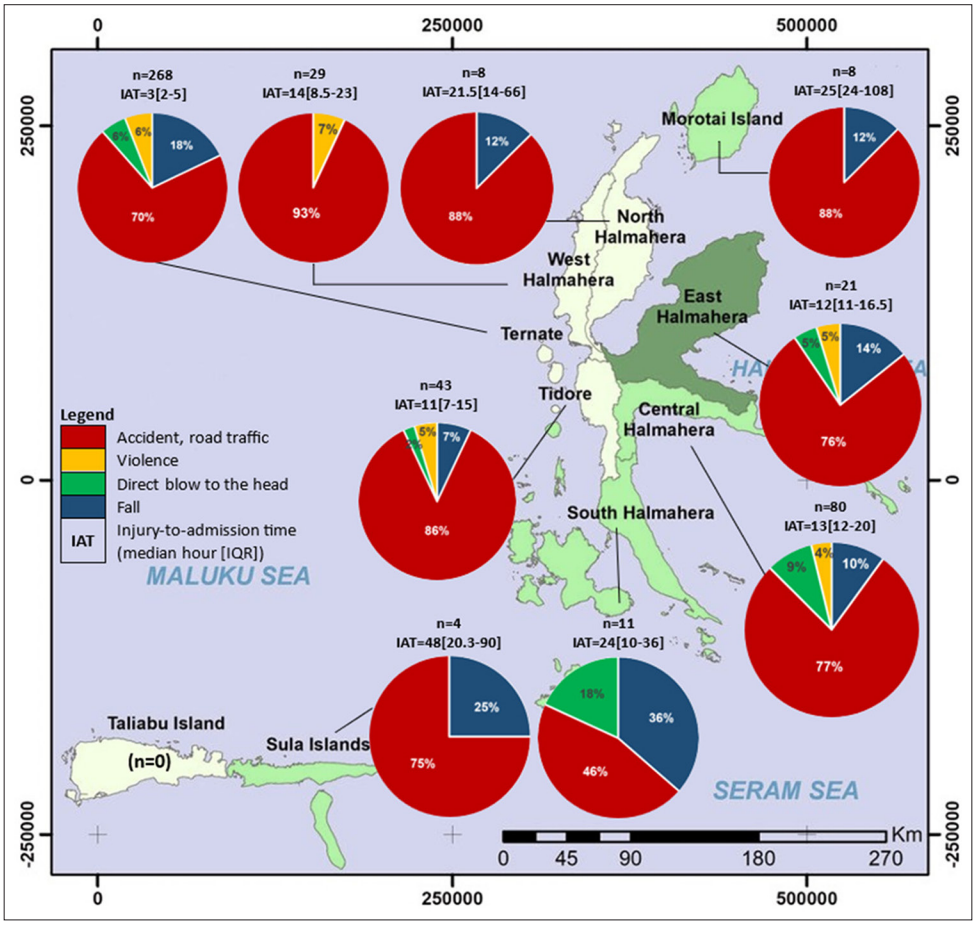

Figure 1: The distribution of acute traumatic brain injury, its causal mechanism, and the median hour interquartile range (IQR) of injury-to-admission time across districts in North Maluku.

Characteristics of all RTA- and motorcycle-related acute TBI patients

There were 353 patients admitted to the hospital following RTA [Table 1]. Their mean age ± SD was 30.5 ± 16.8 years old. The majority were male (64.9%) who paid the medical expenses by non-JKN mechanism (66%), were diagnosed with mild TBI (75.4%), struck by/fell off from motorcycles (91.8%), and had IAT >4 h (56.7%). Significant differences were observed between the alive and deceased groups; compared to the former, the latter was mostly referred from outside Ternate (42.7% vs 86.7%), diagnosed with moderate-severe TBI (18.2% vs 93.3%), showed brain CT abnormalities (48.6% vs 96.7), had IAT >4 h (53.3% vs. 93.3%), and underwent surgery (11.1% vs. 46.7%).

Table 2 shows the demographic and clinical characteristics of motorcycle-related acute TBI cases according to the

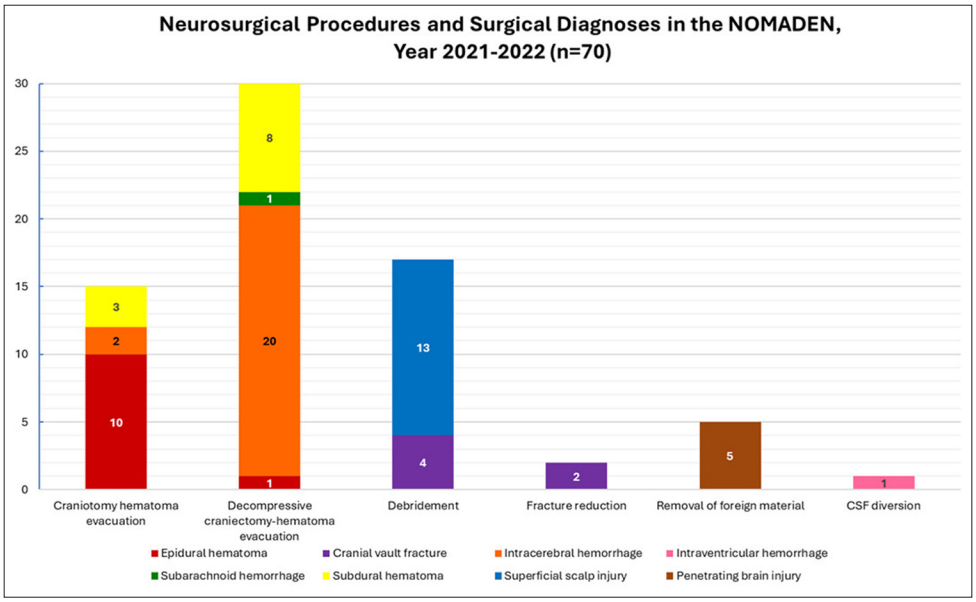

Figure 2: The distribution of neurosurgical diagnoses and procedures performed in North Maluku as recorded by the North Maluku database in the neurosurgery study. CSF: Cerebrospinal fluid.

Table 1: Characteristics of road traffic accident-related acute traumatic brain injury patients, divided by in-hospital mortality (*n*=353).

Variable (s)	All	Alive	Deceased	*P*-value
	n=353	*n*=323	*n*=30	
Age, mean years±SD	30.5±16.8	30.1±16.7	34.9±17.7	0.133
Age ≤17-years-old, *n* (%)	61 (17.3)	58 (18)	3 (10)	0.27
Female, *n* (%)	124 (35.1)	114 (35.3)	10 (33.3)	0.83
National Health Insurance, *n* (%)	120 (34)	102 (31.6)	18 (60)	0.01
Suspected alcohol use, *n* (%)	70 (19.8)	67 (20.7)	3 (10)	0.16
Referred from Ternate, *n* (%)	189 (53.5)	185 (57.3)	4 (13.3)	<0.001
Degree of severity, *n* (%)				
Mild	266 (75.4)	264 (81.7)	2 (6.7)	<0.001
Moderate	55 (15.6)	45 (13.9)	10 (33.3)	
Severe	32 (9.1)	14 (4.3)	18 (60)	
Brain CT abnormalities, *n* (%)	186 (52.7)	157 (48.6)	29 (96.7)	<0.001
Vehicles, *n* (%)				
Motorcycle	324 (91.8)	294 (91)	30 (100)	0.154
Car/truck	29 (8.2)	29 (9)	0 (0)	
Injury-to-admission time, *n* (%)				
0–4 h	153 (43.3)	151 (46.7)	2 (6.7)	<0.001
>4 h	200 (56.7)	172 (53.3)	28 (93.3)	
Surgery performed, *n* (%)	50 (14.2)	36 (11.1)	14 (46.7)	<0.001

SD: Standard deviation, CT: Computed tomography

subject's relationship to the vehicle (n = 324). Overall, the majority were motorcyclists (66.7%), aged >17 years old (84%), male (64.2%), had IAT >4 h (55.9%), paid the medical cost by non-JKN mechanism (66.4%), not suspected to be under alcohol influence (78.4%), referred from Ternate (55.2%), and diagnosed with mild TBI (75%). Forty patients (12.3%) underwent surgery, and 9.3% passed away. Compared to other groups, motorcyclists significantly exhibited the highest proportion of patients with age ≥17 years old, male sex, JKN coverage, suspected alcohol use, and IAT >4 h. Notably, 9.3% and 91.2% of this group were ≤17 years old and did not wear helmets, respectively.

Association between variables and in-hospital mortality

Among the RTA-related TBI patients, following uni- and multivariable analysis, GCS on admission (unadjusted odds ratio [OR] [95% confidence interval (CI)] of 0.56 [0.48–0.65] to multivariable-adjusted OR [95% CI] of 0.57 [0.49–0.68]) and IAT (unadjusted OR [95% CI] of 12.29 [2.88–52.45] to multivariable-adjusted OR [95% CI] of 5.63 [1.02–31.26] were found to be significantly associated with in-hospital mortality [Table 3]. Similar findings were observed among motorcycle-related TBI patients: GCS on admission (unadjusted OR [95% CI] of 0.56 [0.48–0.66] to multivariable-adjusted OR [95% CI] of 0.58 [0.49–0.68]) and IAT (unadjusted OR [95% CI] of 12.90 [3.02–55.15] to multivariable-adjusted OR [95% CI] of 5.44 [1.00–30.34]).

DISCUSSION

The efficiency and effectiveness of public health policy in reducing the burden of TBI depends on a thorough understanding of the disease's epidemiology. Hitherto, the only national data source on TBI is the 2018 Basic Health Research study by the Indonesian Ministry of Health. According to this report, North Maluku was ranked ninth as the province with the highest TBI prevalence. Due to the dynamic and unique social, economic, cultural, and geographical circumstances around TBI epidemiology and management, a standard, up-to-date, and real-world TBI registry tailored to every region in Indonesia is mandatory. As a response, we conducted a prospective cohort study of all motorcycle-related TBI patients managed at Dr. H. Chasan Boesoirie General Hospital in Ternate, North Maluku, Indonesia. Our main purpose was to elaborate on the epidemiology of motorcycle-related TBI, examine the determinants of in-hospital mortality among this particular group, and provide evidence-based suggestions for future policies to curtail this malady.

Similar to our finding, most, if not all, studies from other parts of Indonesia and other nations, particularly from LMICs, have identified male motorcyclists in their thirties, a productive population group, as the predominant group.[1,9,14,21,34,41,45,46] Composed of over 1300 ethnic groups, Indonesia mostly holds patriarchal values that men are the family's main breadwinners, while women are responsible for the household's daily well-being.[43,53] This necessitates men to be outdoors more often to commute to workplaces, presumably using the most economical means of transportation; here, this

Table 2: Characteristics of motorcycle-related acute traumatic brain injury patients, divided by the role of each subject to the vehicle (n=324).

Variable (s)	Motorcyclist	Passenger	Pedestrian	*P*-value
	n=216	*n*=77	*n*=31	
Age, mean years±SD	30.5±14.4	30.4±18.5	31.1±25.5	0.98
Age ≤17 years old, *n* (%)	20 (9.3)	19 (24.7)	13 (41.9)	<0.001
Female, *n* (%)	50 (23.1)	51 (66.2)	13 (41.9)	<0.001
National health insurance, *n* (%)	79 (36.6)	21 (27.3)	9 (29)	0.049
Suspected alcohol use, *n* (%)	65 (30.1)	5 (6.5)	0 (0)	<0.001
Helmet use, *n* (%)	19 (8.8)	2 (2.6)	NA	0.99
Referred from ternate, *n* (%)	111 (51.4)	49 (63.6)	19 (61.3)	0.99
Degree of severity, *n* (%)				
Mild	159 (73.6)	63 (81.8)	21 (67.7)	0.47
Moderate	35 (16.2)	8 (10.4)	7 (22.6)	
Severe	22 (10.2)	6 (7.8)	3 (9.7)	
Brain CT abnormalities, *n* (%)	120 (55.6)	31 (40.3)	14 (45.2)	0.60
Injury-to-admission time, *n* (%)				
0–4 h	81 (37.5)	45 (58.4)	17 (54.8)	0.003
>4 h	135 (62.5)	32 (41.6)	14 (45.2)	
Surgery performed, *n* (%)	26 (12)	10 (13)	4 (12.9)	0.93
In-hospital mortality, *n* (%)	19 (8.8)	8 (10.4)	3 (9.7)	0.83

SD: Standard deviation, CT: Computed tomography

Table 3: Logistic regression analysis for the association between variables and in-hospital mortality among all RTA-related- and motorcycle-related acute traumatic brain injuries.

Variables	Univariable		Multivariable	
	OR	95% (CI)	OR	95%CI
All RTA				
Age	1.02	1.00–1.04	1.01	0.98–1.04
Male (Ref: Female)	0.92	0.42–2.03	1.44	0.47–4.46
Insurance (Ref: NHI)	0.31	0.14–0.70*	0.58	0.10–3.31
Alcohol (Ref: None)	2.36	0.69–8.00	1.78	0.39–8.24
GCS	0.56	0.48–0.65*	0.57	0.49–0.68*
IAT (Ref: 0–4 h)	12.29	2.88–52.45*	5.63	1.02–31.26*
Motorcycle only				
Age	1.02	1.00–1.04	1.01	0.98–1.04
Male (Ref: Female)	1.10	0.49–2.43	1.35	0.43–4.22
Insurance (Ref: NHI)	0.29	0.13–0.66*	1.01	0.17–6.03
Alcohol (Ref: None)	2.66	0.78–9.03	2.25	0.47–10.68
GCS	0.56	0.48–0.66*	0.58	0.49–0.68*
IAT (Ref: 0–4 h)	12.90	3.02–55.15*	5.44	1.00–30.34*

RTA: Road traffic accident, NHI: National health insurance, GCS: Glasgow coma scale, IAT: Injury-to-admission time, CI: Confidence interval, OR: Odds ratio *p < 0.05.

is achieved by either self-owned motorcycles or the currently growing motorcycle taxi.[40] This puts male motorcyclists at a higher risk of experiencing RTA. Psychologically, motorcyclists who travel primarily for work displayed lower behavior scores to avoid harm and higher behavior scores for novelty-seeking, a type of personality characterized by a willingness to take physical, social, legal, and financial risks to experience novelty, consequently increasing their risks of RTA.[44] On another note, regardless of having a 1.2 times higher probability of utilizing hospitals than males do,[30] Gomez *et al*. found that injured females have a 0.9 times lower probability of being transported to trauma centers, especially those severely injured, potentially creating an ecological fallacy.[18]

Nearly a quarter of our motorcyclists and passengers were suspected of alcohol use. Alcohol has been shown to have a major role in global RTA, particularly in several LMICs.[17,58] TBI patients with elevated serum alcohol have 27% higher odds of death compared to their counterparts.[3] In addition, alcohol has a bidirectional association with TBI patients, affecting their neuropsychological and neurobiological properties before and after the injury.[52] Despite these findings, since a validated alcohol screening tool was unavailable in our hospital due to financial constraints, physical examinations performed to investigate signs of alcohol intoxication, for example, the smell of alcohol on breath, facial flushing, etc., may not be accurate, resulting in potential examiner bias.[37]

The 2018 Basic Health Research reported that about 23.9% of motorcyclists and passengers never/rarely wore helmets while commuting.[24] This number is small compared to the data in our region (50.3%). According to one survey, Indonesians deemed helmets impractical because they caused messy hair, were unsuitable for short-distance trips, and were unimportant when police officers were not present.[49] In our study, only 8.8% of motorcyclists wore helmets. We did not include helmet usage as a covariate in the multivariable analysis due to the high proportion of helmetless motorcyclists and passengers (92.8%). Proper helmet use has been proven to reduce death and disability as well as health care costs caused by accidents.[26] By law, the Indonesian government has decreed that motorcyclists and passengers must use helmets that meet the national standards.[28] Nevertheless, the appalling helmet compliance affirms that stronger imposition of mandatory helmet-wearing, including higher fines for any violation of minimum age and maximum speed limits, is necessary to prevent further damage.

Despite its success in attaining more than 90% coverage all across the country, the JKN, as Indonesia's official universal healthcare coverage scheme, has limited utilization for RTA patients.[57] Several requirements are necessary for its eligibility, that is, active membership without the involvement of any other insurance, single-vehicle accident corroborated by official police reports, and non-occupational-related RTA.[23] In this study, 66.4% of motorcycle-related TBI patients had to pay the healthcare costs either by out-of-pocket mechanism (56.2%) or by JR insurance (10.2%). The JKN and JR insurances might provide some financial assistance, up to 20 million Indonesian Rupiah (IDR) and 50 million IDR for alive and deceased patients, respectively. Still, more than half of our study population were left to fend for themselves.[42] Emergency visits and hospitalization due to motorcycle-related TBI have clearly been shown to cost more healthcare resources than other motorcycle-related diagnoses.[20] Meanwhile, poor uptake of health insurance programs and low maximum insurance coverage are the reality in LMICs.[22] Furthermore, regarding the regional economic impact of TBI, Mediratta *et al*. reported that the out-of-pocket mechanism had put 955 million (47.7%) of the SEA population at risk for catastrophic expenditure (taking >40% of household annual income) and another 955 million (47.7%) for impoverishing expenditure (leading to poverty).[32,33] Tailored approaches to increase the uptake of health insurance by providing subsidies, simplifying initial registration, balancing insurance premiums with financial capacity, and giving comprehensive education on its benefits are therefore important to execute.[5]

The proportion of mild TBI in our study is higher than in two other Indonesian-based studies that included patients with all levels of consciousness during admission.[34,45] The authors surmise that besides the low probability of North Maluku

people utilizing hospitals,[30,53] poor pre-hospital service due to an uncoordinated system with substandard equipment and meager emergency capability, combined with difficult geographical conditions might decrease the probability of moderate-to-severe TBI patients, particularly those outside Ternate, of reaching our neurosurgical facility.[8,35]

Less than half of all patients in the study were referred from outside Ternate. No patients were even recorded from Taliabu, the most distant district. The authors postulate several conditions that may complicate neurosurgical patient transfer in the region: (i) the challenging geographical situation of North Maluku, comprising 69% ocean and 805 islands, (ii) the differing distance of each district to the neurosurgery service from the nearest (Tidore, 14.2 km) to the farthest (Taliabu, 449.3 km), (iii) the worst road condition in areas outside Ternate, which were moderate-to-severely damaged in 56.4% of the total road, compared to those in Ternate that reached 19.9%, and (iv) the lack of neurosurgeons and their supporting facilities. These circumstances present serious challenges to improving the management of TBI in North Maluku and necessitate comprehensive cooperation from all related elements.

Underage motorcyclists are of particular concern. The Indonesian Law No. 22 of 2009 on Traffic and Road Transportation defines 17 years old as the minimum age for obtaining a driving license. Nevertheless, this study managed to identify that one per-tenth of all motorcyclists were underage. Of all underage motorcycle-related TBI patients, 38.5% were motorcyclists, and none wore helmets. Several underlying sociocultural and neuroscience factors may be responsible. Young motorcyclists are more overly confident, sensation-seeking, craving social acceptance, and impatient than older ones.[12,54] In LMICs, youngsters have more peer pressure to prove themselves to society, receive more freedom to use motorcycles for school and work purposes, and have less access to public transportation modes.[4] From a neuroscience point of view, the prefrontal cortex, a part of the brain responsible for thought process, personality, and decision making, has not yet evolved optimally in young generations, eliciting their risky and daring behavior.[16]

The GCS has long been known as a simple, valid, and reproducible clinical tool to determine the severity of TBI ever since its introduction in 1974 by neurosurgery professors Teasdale and Jennett.[50] Its sole measurement amid patients' arrival has proven to be significantly associated with in-hospital mortality and equivalent to other trauma score systems, for example, the revised trauma score and the Full Outline of UnResponsiveness score.[2,7] We identified that a 1-point increase in the on-admission GCS resulted in 43% lesser odds of in-hospital mortality among motorcycle-related TBI patients. Therefore, we posit that the higher the on-admission GCS a TBI patient has, the better their outcome. One of the numerous factors influencing this variable is the time of referral to neurosurgery service, or IAT. In this study, motorcycle-related TBI patients with IAT >4 h had 5.4 higher odds of in-hospital death compared to those who arrived sooner. A study by Barthélemy *et al.* on >2000 TBI patients in Cambodia, another LMIC, has a similar conclusion: increasing IAT, particularly >4 h, was significantly related to worsening Glasgow Outcome Scale.[6] According to the Three Delays framework, prolonged care provision may be caused by delays in seeking, reaching, or receiving care.[33] While the IAT in this study may make up the first two points, details constituting this parameter are lacking, for example, previous healthcare facilities visited, the pre-hospital ambulance service utilized, and the factual distance of the journey taken.

High motorcycle volume is one of the profound challenges faced in reducing the burden of TBI due to RTA. Motorcycles are the primary means of land transportation in Indonesia. According to the Traffic Corps National Police Republic Indonesia data, by the end of February 2023, motorcycle

Table 4: The volume of motorcycle units, population, and population/motorcycle unit ratio across North Maluku districts in 2023, and the incidence of mTBI in this study.[28]

Districts	Units	Population	Population/unit	mTBI, *n* (%)
Ternate	137,244	205,001	1.5	179 (55.2)
North Halmahera	46,616	197,638	4.2	6 (1.9)
Tidore	25,040	114,480	4.6	36 (11.1)
South Halmahera	19,783	248,395	12.6	5 (1.5)
West Halmahera	19,328	132,349	6.9	26 (8)
Central Halmahera	12,231	56,802	4.6	49 (15.1)
East Halmahera	10,161	197,638	19.5	14 (4.3)
Morotai	7,484	74,436	9.9	7 (2.2)
Sula Islands	6,450	104,082	16.1	2 (0.6)
Taliabu Islands	716	58,047	81.6	0 (0)
(Unknown)	23,544	N/A	N/A	N/A
Total	308,597	1,282,937	4.2	324 (100)

mTBI: Motorcycle-related traumatic brain injury, N/A: Not applicable

volume has reached 127,976,339 units or 87% of all means of land transportation.[27] In North Maluku, 308,957 motorcycle units were registered, comprising 89.1% of all means of land transportation. By districts, Ternate has the highest volume of motorcycles (43.9%, 1.5 person/unit), while Taliabu has the least (0.3%, 81.6 person/unit), directly proportional to the TBI incidence in each district [Table 4]. A country's national motorcycle sales have been proven to be proportionate to its RTA incidence.[38] Without limitations on motorcycle ownership, strict enforcement of the traffic law, and improvement of road conditions, a greater increase in TBI prevalence and its related morbidity are to be expected in the future.

As the first attempt to map TBI incidence in the region, the authors realize that future development is necessary to enhance the register's functionality and generalizability. Regionally, international collaboration and standardization with renowned TBI registries, namely, the International TBI Research and the Global Epidemiology and Outcomes following TBI registry, will benefit the people of North Maluku.[25,31] Nationally, a joint effort from all parts of Indonesia to create a comprehensive, integrated, tailored, feasible, and realistic guideline of TBI management at each level of care in Indonesia, just like what has been done in Colombia, is recommended.[47]

Limitations

Apart from the drawbacks mentioned earlier in this study and our primary study, particular limitations are critical to note. Precise information on the type of motorcycles involved in the RTA, for example, small versus large engines, new versus used, and the form of collision, for example, motorcycle versus motorcycle, motorcycle versus car collision, were not obtained. Lists of the healthcare facilities visited, and the transportation modes utilized before reaching our facility were absent. Other related abnormalities in the brain CT during the 1st year of the study might be overlooked due to the shortage of radiologists. Finally, due to poor recording of medical records, the actual duration from patients' arrival until the administration of definite care was unavailable.

CONCLUSION

Our study presents the epidemiology pattern of TBI caused by motorcycle RTAs and the variables associated with in-hospital mortality in the only neurosurgical center in Ternate, North Maluku. In general, the dominant characteristics of the study population were male motorcyclists around their thirties who did not wear helmets, paid their medical expenses using the non-JKN mechanism, suffered accidents in/referred from Ternate, diagnosed with mild TBI, and arrived at the hospital in >4 h after injury. IAT and GCS on admission were significantly related to both in-hospital mortality among RTA-related and motorcycle-related TBI patients. Of particular attention, one per-tenth of motorcyclists were <17 years old, a group forbidden by law to operate motor vehicles. These are hard evidence for a major overhaul of road safety in North Maluku. Improved medical service capacity, better governance, reinforced law, and persistent education to society are imperative. Finally, neurosurgeons are obliged to take the battle to reduce the burden of TBI outside of the operating theater and actively participate in deciding the best policy for TBI management.

Ethical approval

Ethical clearance for this study has been obtained from the Institutional Review Board, Universitas Khairun (No. 57/UN27.06.11/KEP/EC/2023). The approval date of the ethical clearance is November 6th 2023.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent.

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Conflicts of interest

There are no conflicts of interest.

Use of artificial intelligence (AI)-assisted technology for manuscript preparation

The authors confirm that there was no use of artificial intelligence (AI)-assisted technology for assisting in the writing or editing of the manuscript and no images were manipulated using AI.

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