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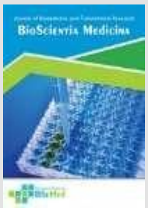

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Longitudinal Observational Analysis of Traumatic Brain Injury Epidemiology and Pre-Hospital Intervals During the COVID-19 Pandemic in a West Java Tertiary Center

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A B S T R A C T

Background: The COVID-19 pandemic necessitated large-scale social restrictions (PSBB) in Indonesia, drastically altering population mobility and, consequently, the landscape of neurotrauma. While the reduction in road traffic Incidents (RTIs) during lockdowns is well-documented, the collateral impact on the golden hour—the critical pre-hospital interval for traumatic brain injury (TBI) resuscitation—remains under-researched in lower-middle income countries (LMICs). This study analyzes the longitudinal shifts in TBI epidemiology, injury mechanisms, and hospital admission intervals across pre-pandemic, pandemic, and relaxation phases. **Methods:** This retrospective observational study analyzed 1,519 TBI patients admitted to the Emergency Department of Dr. Hasan Sadikin General Hospital (RSHS), a tertiary referral center in West Java, from January 2019 to December 2021. The cohort was stratified into three phases: Pre-Pandemic (2019), Pandemic/PSBB (2020), and Relaxation (2021). Variables included demographics, injury mechanisms, Glasgow Coma Scale (GCS), loss of consciousness (LOC), and Hospital Admission Interval (MRS). **Results:** Total TBI admissions exhibited a sharp V-shaped trend, decreasing by 75% in 2020 compared to 2019, driven by a collapse in RTI volume (490 to 107 cases). Admissions rebounded in 2021 (n=705). Males (78.4%) and young adults (15-24 years) constituted the majority, with RTI accounting for 74.78% of all mechanisms. While pediatric (0-4 years) and geriatric (≥65 years) groups were prone to falls, the most critical finding concerned pre-hospital delays. Despite reduced traffic density, only 3.23% of patients arrived within the golden hour (<1 hour). The majority (40.42%) arrived between 5-12 hours, and a significant cohort (17.44%) experienced delays exceeding 12 hours, indicating persistent systemic barriers to rapid care regardless of road conditions. **Conclusion:** The pandemic successfully suppressed TBI volume through mobility restrictions but failed to improve pre-hospital admission times. The persistence of significant delays (>5 hours) for the vast majority of patients highlights that the barriers to the golden hour in Indonesia are structural rather than traffic-dependent. Future trauma systems must address these pre-hospital inefficiencies to improve outcomes.

1. Introduction

Traumatic brain injury (TBI) stands as one of the most persistent and devastating global health challenges of the 21st century. Often described as a silent epidemic, TBI contributes disproportionately to morbidity and mortality, particularly within the young and productive demographics of lower-middle income countries (LMICs).[1] In the specific context of Indonesia, the epidemiology of neurotrauma is inextricably linked to the nation's unique transportation infrastructure, which is dominated by two-wheeled motorized vehicles.[2] The resultant high-energy trauma places an immense burden on neurosurgical services, where patient outcomes are heavily contingent upon the timeliness and efficacy of early intervention.[3]

The concept of the golden hour in neurotrauma is paramount. It posits that the immediate post-injury period is critical for preventing secondary brain injury.[4] During this window, interventions aimed at maintaining cerebral perfusion pressure (CPP), optimizing oxygenation, and rapidly evacuating mass lesions (such as epidural or subdural hematomas) can aggressively halt the biochemical cascades of excitotoxicity and ischemia that lead to permanent neuronal death. In densely populated urban centers like Bandung, West Java, achieving this Golden Hour is frequently impeded by severe traffic congestion and fragmented pre-hospital emergency medical services (EMS).[5]

The onset of the COVID-19 pandemic in early 2020 introduced a radical, albeit involuntary, variable into this epidemiological equation. To curb viral transmission, the Indonesian government implemented *Pembatasan Sosial Berskala Besar* (PSBB), or Large-Scale Social Restrictions. These measures strictly limited non-essential travel, schooling, and office work, effectively altering the population's mobility patterns.[6] Theoretically, such restrictions should result in a dual phenomenon: a significant reduction in trauma volume due to decreased road exposure, and potentially faster hospital presentation times due to the alleviation of traffic congestion.[7]

However, the reality of the pandemic's impact on trauma systems is multifaceted.[8] While reduced traffic density might theoretically expedite transport times for the few who are injured, fear of viral exposure (nosocomial infection), overwhelmed healthcare systems, and the repurposing of ambulances for pandemic response may conversely delay hospital presentation. Existing literature from high-income countries (HICs) has largely documented these trends, but data from Southeast Asia, specifically Indonesia, remains sparse.[9] Understanding how a pandemic-induced lockdown alters the mechanisms of injury—shifting potentially from high-velocity road trauma to domestic incidents like falls—and how it impacts the critical hospital admission interval (MRS) is vital for future disaster planning.

This study offers a unique longitudinal analysis spanning three distinct epidemiological phases: the baseline normal (2019), the intense lockdown (2020), and the relaxation/new normal (2021). Unlike previous cross-sectional snapshots, which often aggregate data or look only at the initial lockdown phase, this research dissects the granularity of the golden hour metrics in an LMIC tertiary setting over a full three-year cycle. It specifically questions whether the empty roads of the lockdown translated into improved access to life-saving neurosurgical care, offering a rare insight into the resilience of the trauma referral network in West Java.[10] The primary aim of this study is to evaluate the characteristics of Traumatic Brain Injury admissions over a three-year period at Dr. Hasan Sadikin General Hospital. We aim to analyze the shifts in injury mechanisms, demographic vulnerabilities, and specifically the hospital admission intervals (MRS) to determine the impact of COVID-19 restrictions on the timeliness of neurotrauma management and to identify systemic barriers that persist independent of traffic conditions.

2. Methods

We conducted a descriptive, retrospective observational study utilizing electronic medical records from Dr. Hasan Sadikin General Hospital (RSHS), Bandung. RSHS serves as the primary tertiary referral center (Type A Hospital) for West Java, a province with a population density heavily reliant on motorcycle transport. The hospital serves as the apex of the referral pyramid for a catchment area exceeding 48 million people, managing the highest complexity of neurosurgical cases. The study period encompassed three years, from January 1st, 2019, to December 31st, 2021. To capture the dynamic changes in public policy and mobility, the cohort was stratified into three distinct phases: Phase I (2019 - Pre-Pandemic): Baseline data representing normal trauma patterns in West Java; Phase II (2020 - Pandemic/PSBB): The period of strict social restrictions, school closures, and high community anxiety; Phase III (2021 - Relaxation): The period of easing restrictions and gradual return to economic mobility. The study population included all patients presenting to the Emergency Room (IGD) with a primary clinical diagnosis of head injury (Commotio Cerebri, Contusio Cerebri, Epidural Hematoma, Subdural Hematoma, etc.) confirmed by clinical examination and radiological imaging (CT scan). Exclusion criteria were applied to patients with incomplete medical records regarding key variables (mechanism of injury, GCS, or admission time) or those who were Dead on Arrival (DOA) without resuscitative efforts. Data were extracted and anonymized to preserve patient confidentiality.

The primary variables analyzed included: Demographics: Age (stratified into 0-4, 5-14, 15-24, 25-44, 45-64, and ≥65 years) and Gender (Male/Female). Clinical Presentation: Glasgow Coma Scale (GCS) on admission, categorized as Mild (GCS 14-15), Moderate (GCS 9-13), and Severe (GCS 3-8). The history of Loss of Consciousness (LOC) was recorded as a binary variable (Yes/No). Injury Mechanism: Classified into Road Traffic Incidents (RTI), Falls, Abuse/Violence, and Others. Admission Interval (MRS): Defined as the time elapsed between the injury event and hospital arrival. This variable acts as a surrogate marker for the efficiency of the pre-hospital and referral systems. Intervals were stratified into: <1 hour (Golden Hour), 1-4 hours, 5-12 hours, and >12 hours. Data were tabulated and analyzed using descriptive statistics to identify trends across the three distinct timeframes. Frequency distributions and percentages were calculated for all categorical variables. To ensure granularity, data were de-aggregated by year to visualize the specific impact of the 2020 restrictions compared to the 2019 baseline and the 2021 rebound.

3. Results

Figure 1 presents a striking graphical representation of the longitudinal epidemiological shift observed at Dr. Hasan Sadikin General Hospital (RSHS) over the three-year study period (2019–2021). The visualization forms a distinct, sharp V-shape, providing compelling visual evidence of the profound impact that large-scale population mobility restrictions had on neurotrauma incidence in a major Indonesian tertiary center. This figure serves not merely as a record of hospital admissions but as a validation of fundamental injury prevention theories in an LMIC setting heavily reliant on motorized transport. The trajectory begins on the left with the 2019 Pre-Pandemic Baseline, represented by a robust blue bar reaching the highest point on the y-axis (estimated ~651 total cases, with 490 confirmed RTIs). This phase characterizes the normal state of neurotrauma in West Java: a high volume of injuries driven primarily by dense, chaotic road traffic and high economic mobility. This baseline establishes the immense burden routinely placed on the neurosurgical referral network prior to the global health crisis. The center of the figure is dominated by the dramatic trough of 2020: The Pandemic (PSBB) Phase, represented by a sharply reduced red bar. Coinciding precisely with the implementation of strict Large-Scale Social Restrictions (*Pembatasan Sosial Berskala Besar*), total TBI admissions plummeted by 75% from the baseline. This massive suppression of volume was driven almost exclusively by the evaporation of Road Traffic Incidents (RTIs), which dropped from 490 cases in the previous year to just 107. Scientifically, this phase serves as a potent real-world validation of the Haddon Matrix's pre-event phase strategies. By mandating stay-at-home orders and closing schools and offices, government policy effectively removed the host (the motorcyclist and commuter) from the high-risk environment (the open road), thereby severing the kinetic chain of injury causation before it could begin. This data point underscores a critical epidemiological reality in developing nations: neurotrauma volume is almost linearly dependent on economic mobility and road exposure. However, the right side of the figure, represented by the prominent green bar for 2021: The Relaxation Phase, illustrates the fragility of these gains. As restrictions were eased and society adapted to the new normal, trauma volumes rebounded rapidly to 705 cases (accounting for 46.4% of the entire three-year cohort). This resurgence indicates that the safety gains of 2020 were transient and extrinsic, enforced by policy rather than achieved through intrinsic improvements in road safety culture or infrastructure. The rebound reflects a combination of economic necessity forcing the population back to work and widespread restriction fatigue. The connecting trend line overlaying the bars visually emphasizes this elasticity, showing how quickly trauma incidence snapped back to near pre-pandemic levels once the artificial suppressor of lockdown was removed. Ultimately, Figure 1 demonstrates that while mobility restriction is a highly effective short-term injury prevention tool, it is not a sustainable long-term strategy for trauma management.

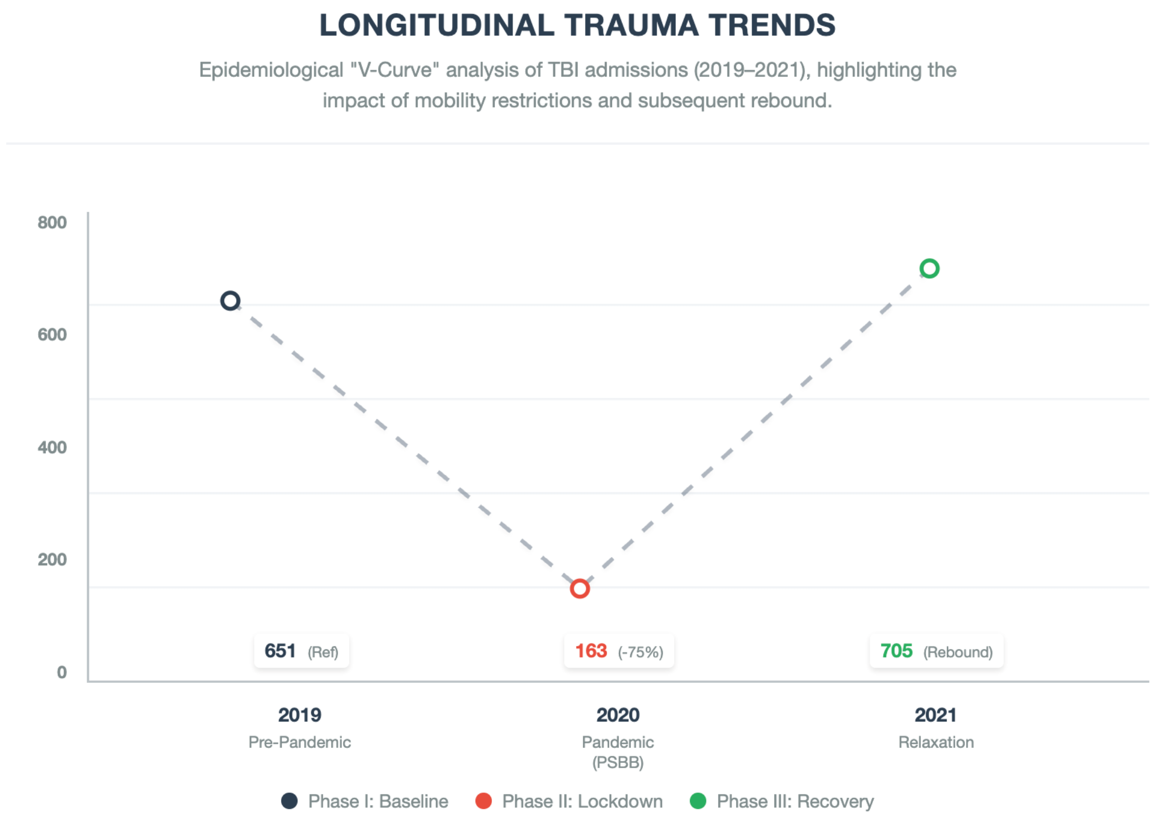

Figure 1. Longitudinal trauma trends.

Figure 2 utilizes a split-panel schematic to illustrate the profound shift in injury mechanisms that occurred beneath the surface of the aggregate data. While road traffic incidents (RTIs) remained the dominant mechanism overall across the three years, this figure dissects how the lockdown environment of 2020 fundamentally altered the risk landscape, trading high-velocity road trauma for insidious domestic hazards, particularly affecting the most vulnerable demographic extremes. The left panel, titled RTI volume collapse, provides a focused visualization of the data driving the V-curve seen in Figure 1. Two vertical bars dramatically contrast the volume of road traffic injuries between the baseline year and the lockdown year. The 2019 bar stands tall, representing 490 confirmed RTI cases—the defining characteristic of West Java's pre-pandemic trauma burden. Beside it, the 2020 bar is vastly diminished, visually representing the collapse to only 107 cases. A prominent drop-down arrow explicitly quantifies this as a massive reduction, emphasizing the direct correlation between reduced traffic density and the prevention of high-energy trauma. This panel reinforces the concept that the primary driver of neurosurgery admissions in this region is the motorcycle; remove the motorcycle from the road, and the primary epidemic subsides. However, the right panel, titled age-specific vulnerability (Falls), reveals the hidden second epidemic that persisted within the home. When the noise of road traffic trauma was silenced, the signal of domestic falls became overwhelmingly clear in specific age groups. The horizontal bar charts highlight that among the Pediatric population (0-4 years), falls accounted for a staggering 54.9% of all TBIs. The figure includes a crucial biomechanical annotation explaining this vulnerability: toddlers possess a higher center of gravity relative to their height and have thinner, less mineralized cranial tables. Confinement to the home during the pandemic likely increased their exposure duration to environmental hazards like stairs, furniture, and slick floors, leading to significant, albeit lower-velocity, head injuries. Figure 2 highlights the Geriatric population (≥65 years), where falls constituted 36% of injuries. The scientific annotation details the distinct pathophysiology in this group: cerebral atrophy associated with aging leads to a stretching of the bridging veins that traverse the subdural space. Consequently, even minor domestic impacts—a slip in the bathroom or a trip over a rug—can generate sufficient shear force to tear these fragile vessels, leading to Chronic Subdural Hematomas (cSDH). The isolation of the pandemic may have also contributed to unobserved falls, delaying discovery and admission. By contrast, the young adult bar at the bottom serves as a control, showing that for the 15-24 age group, RTIs remained dominant even with reduced overall numbers. Figure 2 ultimately illustrates a crucial public health lesson: safety is not merely the absence of road dangers; hazard exposure shifts dynamically with social policy, necessitating targeted domestic safety initiatives during periods of confinement.

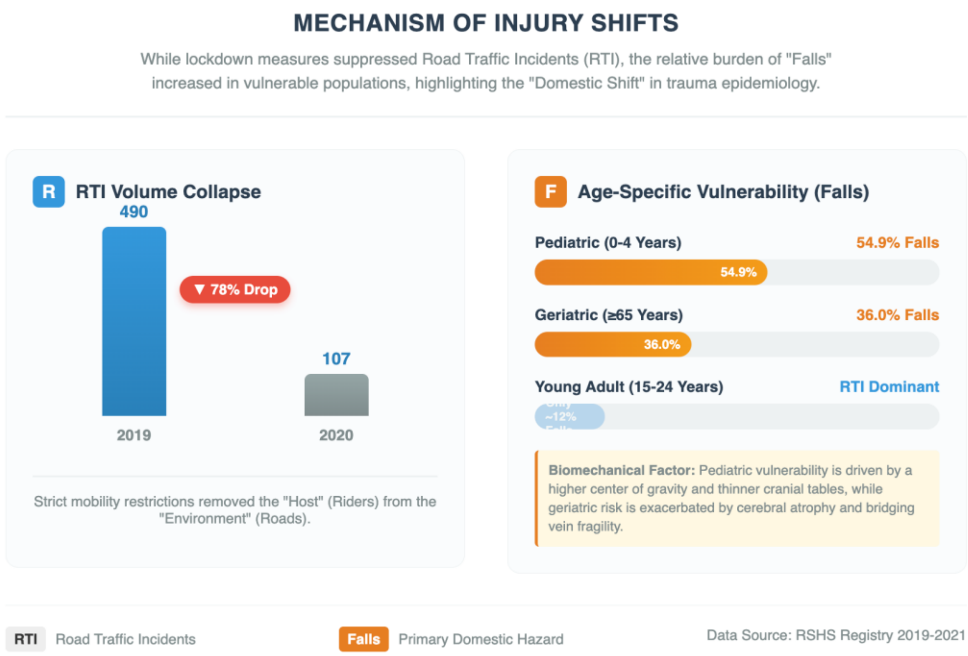

Figure 2. Mechanism of injury shifts.

Figure 3 provides a comprehensive dashboard visualization of the demographic characteristics of the 1,519 TBI patients, highlighting the immutable socio-economic drivers of neurotrauma in Indonesia. The figure uses a dual-panel approach to starkly illustrate that TBI in this setting is not a random event uniformly distributed across the population, but rather a highly specific disease burden shouldered by young, productive males engaged in economic activity. The left panel features a striking Gender Predominance donut chart. The visualization is dominated by a large, dark slate segment representing Males, who constitute 78.4% of the entire cohort—a ratio of nearly 4:1 compared to females. This overwhelming male predisposition is not merely a biological artifact but a reflection of deeply ingrained cultural and economic norms in West Java, where males are the primary breadwinners and commuters. The heavy reliance on two-wheeled motorized vehicles for daily transport to factories, offices, and informal labor markets exposes this demographic to consistent high-energy risks. The accompanying annotation emphasizes that this gender imbalance is typical of LMIC trauma epidemiology, where the primary workforce faces the highest environmental hazards on the road. The right panel, Age Distribution & Risk Peaks, uses a horizontal histogram to map risk across the lifespan, identifying a critical zone of vulnerability. While pediatric and geriatric groups show distinct, smaller peaks related to falls (as detailed in Figure 2), the histogram clearly shows that TBI is predominantly a disease of the young and economically active. The bars for the 15-24 year group (30.7%) and the 25-44 year group (29.0%) are the longest, collectively accounting for nearly 60% of all trauma cases. The 15-24 year bar is highlighted with a peak incidence badge and a high-risk color schema, emphasizing it as the most vulnerable segment. Scientifically, this peak correlates with a confluence of factors: this demographic has the highest exposure to motorcycle travel for school and entry-level employment, combined with a biological predisposition toward risk-taking behavior as frontal lobe executive function continues to mature into the mid-20s. The bottom section of the figure includes a critical Socio-Economic Impact insight box. It explicitly articulates the broader implications of this demographic data: because injuries are concentrated in the 15-44 year productive age bracket, the burden of TBI extends far beyond immediate medical costs. Every severe injury or death in this group represents a potential decades-long loss of economic productivity for a family and the region. Furthermore, the high kinetic energy transfer associated with motorcycle accidents in this young demographic correlates with more severe injuries and higher rates of diffuse axonal injury, frequently resulting in long-term disability that removes the primary earner from the household economy. Figure 3 ultimately portrays TBI as a significant socio-economic destabilizer, driven by the intersection of workforce mobility and transport infrastructure.

Figure 4 offers a nuanced examination of the clinical presentation of the study cohort, challenging the conventional reliance on the Glasgow Coma Scale (GCS) as the sole determinant of injury severity in the acute setting. Through a combination of a severity distribution chart and a correlation analysis with Loss of Consciousness (LOC), this figure visually argues that a classification of mild TBI often conceals significant intracranial insults that necessitate tertiary-level evaluation. The left panel features a GCS Severity Distribution conic chart. On the surface, the data appear reassuring: the chart is dominated by a large green segment indicating that 66.5% (n=1,011) of all patients presented with a mild GCS score of 14–15. Moderate TBI (GCS 9-13) accounts for 24.5%, and Severe TBI (GCS 3-8) represents the smallest fraction at 9.0%. In many triage protocols, GCS 15 patients might be considered low priority. However, this figure serves to caution against such oversimplification in a high-energy trauma environment. The right panel, Prevalence of LOC by Group, provides the critical pathophysiological context that reframes the GCS data.

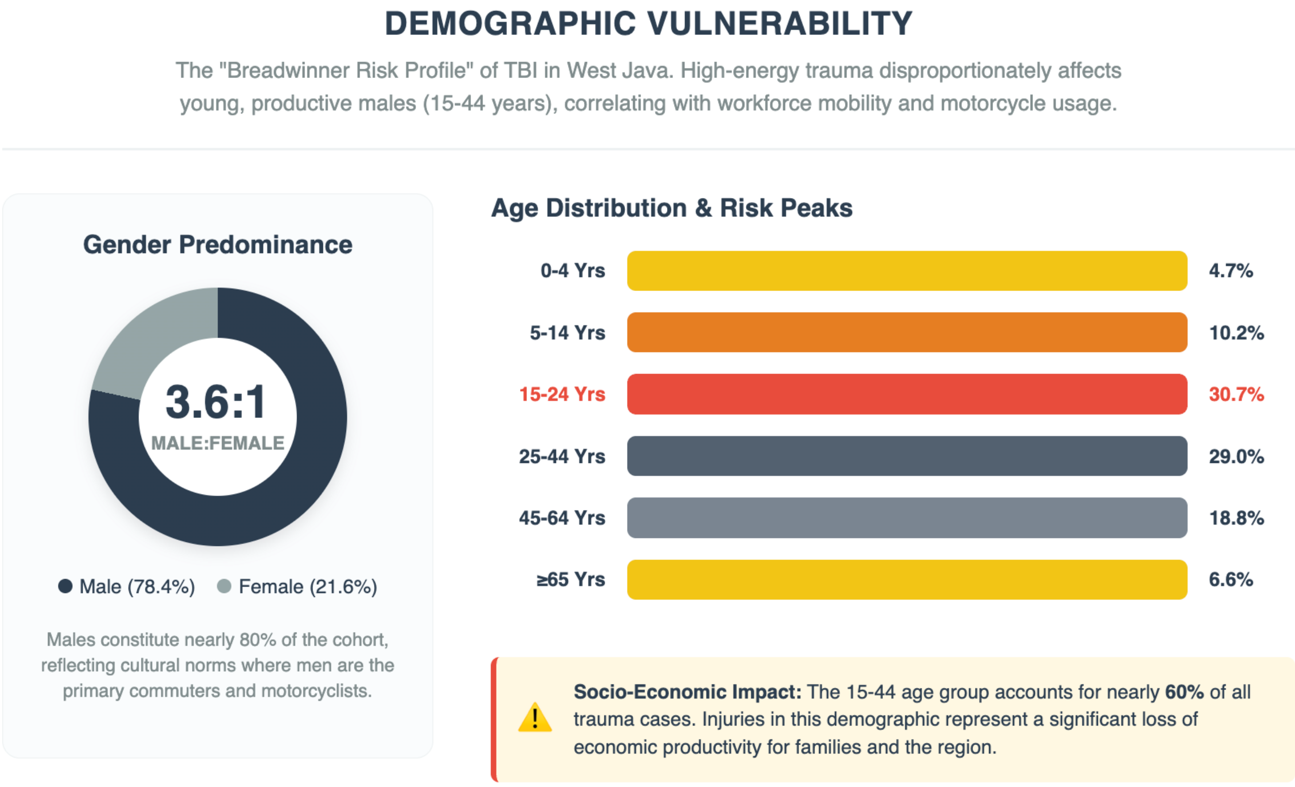

Figure 3. Demographic vulnerability.

It uses progress bars to visualize the percentage of patients within each severity category who experienced a witnessed history of loss of consciousness. While it is expected that nearly all severe (97.1%) and most moderate (87.3%) patients experienced LOC, the striking finding is in the top bar: 45% of the mild TBI group experienced LOC. Scientifically, Loss of Consciousness at the moment of impact is a powerful surrogate marker for the physics of the trauma. It indicates that sufficient rotational or acceleration-deceleration forces were transmitted to the brainstem to transiently disrupt the reticular activating system (RAS), which regulates wakefulness. This biomechanical threshold is significant. Even if the patient has regained full consciousness (GCS 15) by the time they arrive at the ED, the history of LOC suggests a high probability of microscopic shearing injuries to axons (diffuse axonal injury precursor), micro-hemorrhages, or concussive pathophysiology that a simple GCS score cannot detect. The figure's footer emphasizes the clinical insight: these mild patients are not merely suffering from superficial scalp lacerations or stress reactions. Nearly half of them have suffered a genuine concussive brain insult. Their presence in a tertiary trauma registry is validated because they require careful neurological observation and neuroimaging to rule out delayed intracranial hemorrhage, particularly in the context of the high-energy motorcycle mechanisms prevalent in the study. Figure 4 strongly suggests that triage systems in this setting must weigh the history of LOC heavily, rather than relying solely on the arrival GCS, to capture the true burden of hidden intracranial injury.

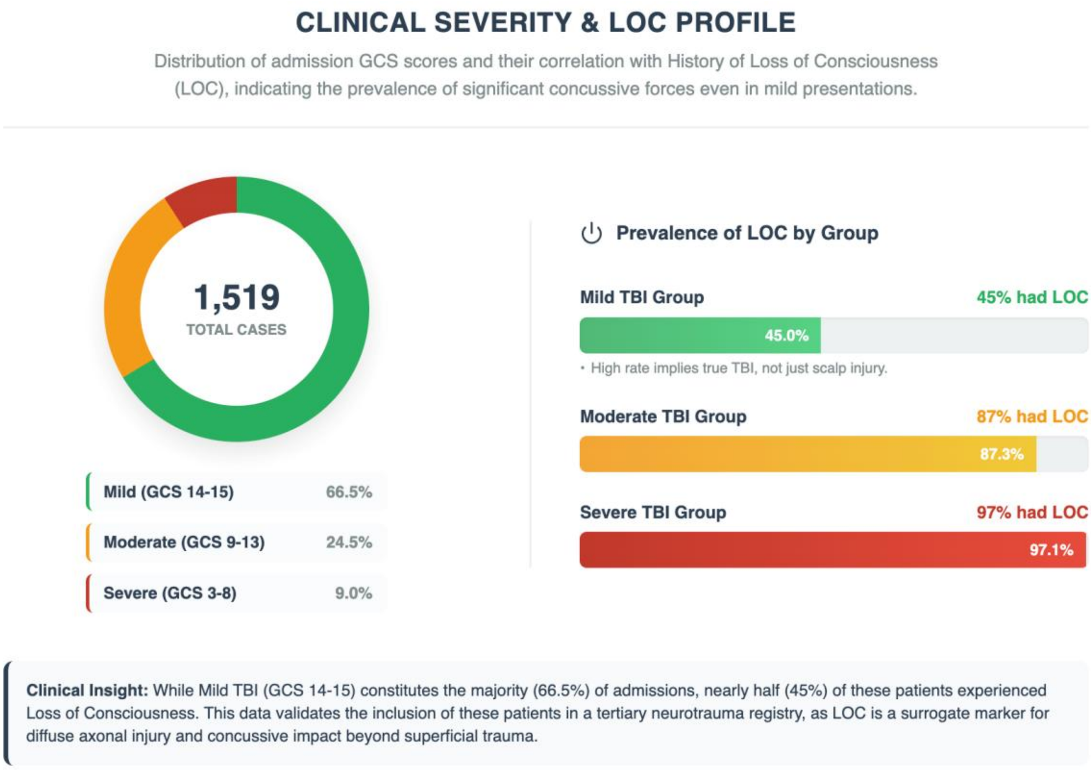

Figure 4. Clinical severity and LOC profile.

Figure 5 is arguably the most critical visualization in the entire study, presenting a stark and troubling analysis of the Hospital Admission Intervals. It uses a color-coded horizontal bar chart to categorize the time elapsed between injury and arrival at the tertiary center, contrasting the biological urgency of neurotrauma with the logistical reality of the Indonesian pre-hospital system. The figure serves as visual proof that the theoretical benefit of reduced traffic during the pandemic did not translate into faster access to life-saving care, pointing instead to deep-seated structural failures. The top row, labeled < 1 Hour: Golden hour, is visually diminutive. A tiny green bar registers that only 3.23% (n=49) of the 1,519 patients arrived within the optimal window for neuroprotective intervention. This finding is profoundly significant. Pathophysiologically, the first hour is critical for reversing cerebral hypoxia, managing hypotension, and surgically evacuating rapidly expanding mass lesions like epidural hematomas before herniation occurs. The virtual absence of patients in this category indicates that the tertiary trauma system is almost entirely reactive rather than proactive in the hyper-acute phase. The subsequent rows visualize the extent of the delays. The 1-4 Hours: Acute phase bar shows 38.91% of arrivals, representing a standard, albeit delayed, acute referral window. However, the data becomes alarming in the bottom half of the chart. The largest single group is the 5-12 Hours: Sub-acute category, comprising 40.42% of patients. The final bar shows that 17.44% arrived after >12 Hours. The clinical note annotations on the bars emphasize the biological consequences of these times. By 5-12 hours post-injury, the cascade of secondary brain injury—involving glutamate excitotoxicity, mitochondrial failure, free radical generation, and blood-brain barrier breakdown—is well established. Cerebral edema is likely escalating, and the penumbra of salvageable brain tissue is shrinking rapidly. Patients arriving after 12 hours are often entering a phase of damage control rather than neuroprotection. The prominent systemic failure indicator box at the bottom synthesizes the core finding: nearly 58% of all patients arrived more than 5 hours after their injury. Crucially, the manuscript text notes that this distribution pattern remained consistent across 2019, 2020, and 2021. The fact that these extreme delays persisted even during the 2020 lockdown, when roads were demonstrably clear of traffic, provides powerful evidence to debunk the assumption that congestion is the primary barrier. Instead, Figure 5 indicates system II failures: inefficient inter-hospital referral protocols, a scarcity of ambulances (likely repurposed for COVID-19), complex financial/administrative hurdles before transfer, and patient hesitation due to fear of the pandemic. Figure 5 stands as a call to action for structural reform in the pre-hospital network.

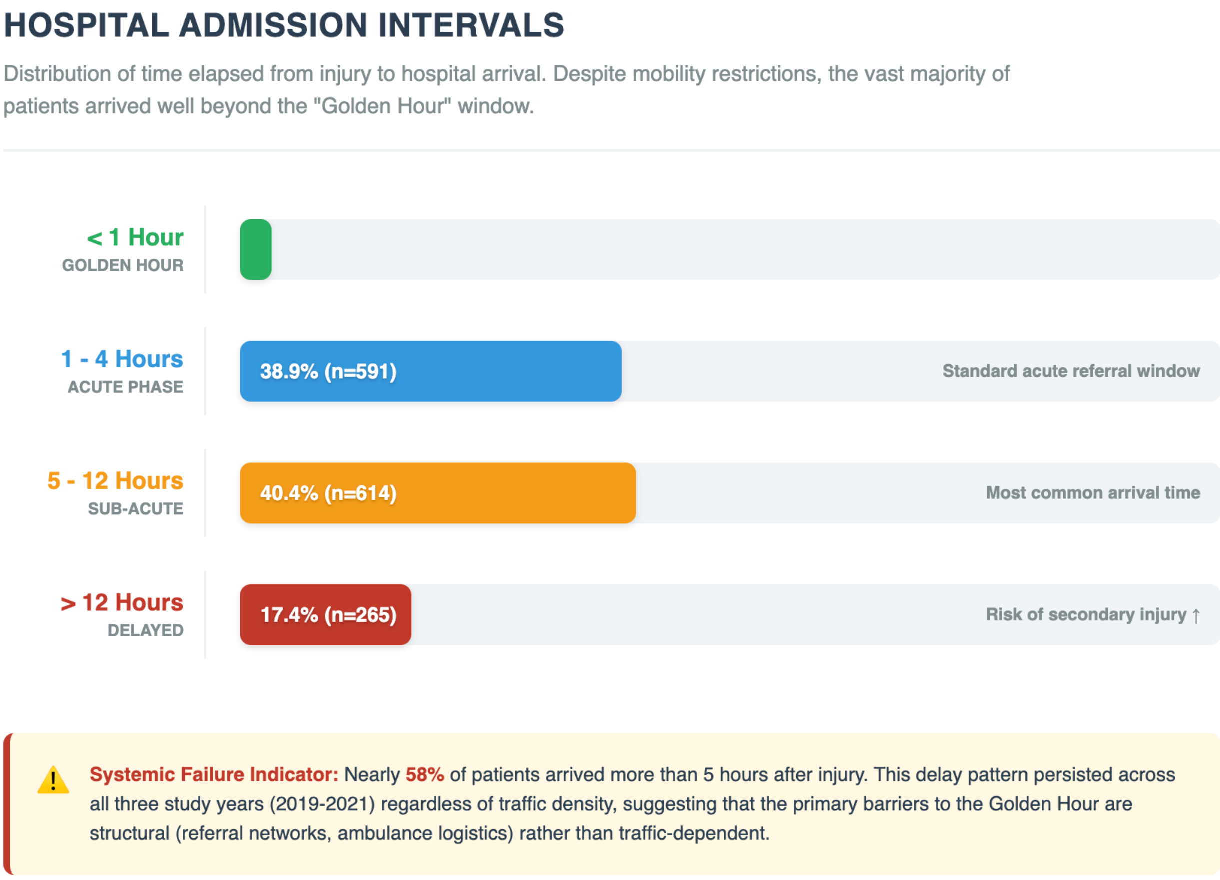

Figure 5. Hospital admission intervals.

4. Discussion

Figure 6 represents the conceptual apex of this study, synthesizing the epidemiological findings into a powerful schematic that visualizes the profound disconnect between the biological imperative of acute neurotrauma and the logistical realities of the pre-hospital system in a tertiary Indonesian setting. Figure 6 functions as a temporal map, correlating the invisible, microscopic cascade of secondary brain injury with the tangible, recorded hospital admission intervals of the 1,519 patients in the cohort. It serves as a visual indictment of a system where the golden hour is not merely missed but is functionally non-existent for the overwhelming majority of patients, translating systemic inefficiencies into irreversible neuronal loss.[11] Figure 6 is structured as a left-to-right timeline, divided into four distinct chronological pillars that trace the evolution of a traumatic brain injury (TBI) from the moment of impact through critical therapeutic windows. Spanning across the background is a connective timeline track that transitions color-wise from a deep impact blue to a hopeful green, a warning orange, and finally a critical red, visually symbolizing the progressive closing of the window for optimal neurosurgical intervention.[12] The timeline begins on the far left with the first pillar, marked T=0: impact. This column represents the instantaneous, irreversible primary injury. The iconography of a collision emphasizes that this is the kinetic event—the mechanical shearing of axons, the contusion of brain parenchyma against the skull ridges, and the immediate rupture of blood vessels. Scientifically, this phase is characterized by immediate structural damage that cannot be undone by any medical intervention.[13] The clinical goal from this second onward is not to repair the primary damage, but solely to prevent what follows. The second pillar introduces the most critical concept in acute neurosurgery: the 0 - 1 Hr: Reversible Phase, famously known as the Golden Window. This column is highlighted in green, symbolizing viability and hope. The pathophysiological annotations within this card detail why time is of the essence. It describes the existence of the ischemic penumbra—a zone of neural tissue surrounding the core injury that is hypoperfused and functionally stunned, yet structurally intact and salvageable if blood flow and oxygenation are rapidly restored.[14] However, this phase is characterized by a highly volatile molecular environment, noted in the figure as involving massive glutamate release. This excitatory neurotransmitter flood overstimulates neuronal receptors, leading to a toxic influx of calcium ions that triggers cell death pathways. The brain state is summarized as optimal intervention, indicating that immediate resuscitation, control of hypoxia/hypotension, and rapid surgical decompression (for an expanding epidural hematoma) during this window can arrest these cascades and preserve the penumbra, fundamentally altering the patient's long-term prognosis.[15] Crucially, the bottom of this column features a data overlay box presenting the study's most sobering finding: only 3.2% of the patient cohort arrived within this window. This stark statistic visually quantifies the failure of the pre-hospital system. It indicates that for 96.8% of patients, the opportunity to intervene during the brain's most salvageable phase was lost before they ever reached specialized care, regardless of whether traffic was gridlocked in 2019 or free-flowing during the 2020 pandemic lockdowns. The timeline progresses to the third pillar, the 1 - 5 Hrs: Escalation phase, colored in a warning orange. Biologically, this window represents a critical transition where the mechanisms of secondary injury begin to overwhelm the brain's compensatory reserves.[16] The annotated pathophysiology highlights mitochondrial failure, indicating that the cellular energy powerhouses are becoming doomed by the calcium overload initiated in the first hour. This leads to a collapse in energy production (ATP) necessary to maintain cellular homeostasis. Simultaneously, oxidative stress begins to damage cellular membranes, and any intracranial hematomas are likely continuing to expand, exerting increasing pressure on surrounding structures. The brain state is succinctly described as window closing. The data overlay for this phase shows that 38.9% of patients arrived during this sub-acute interval. While intervention here is still vital to prevent death and mitigate further damage, the optimal opportunity to preserve the penumbra in its entirety has likely passed. The final and largest pillar on the right represents the > 5 Hrs: Damage phase, colored in a critical red. This column visualizes the establishment of profound secondary injury. The pathophysiology listed here is devastating: Cerebral edema becomes the dominant pathological process, as the breakdown of the blood-brain barrier (BBB) allows fluid to leak into the brain parenchyma, causing it to swell within the fixed confines of the skull. This leads to raised intracranial pressure (ICP), which further compresses blood vessels, worsening ischemia in a vicious cycle. At the cellular level, widespread cell death via necrosis and apoptosis is occurring. The brain state is categorized as secondary injury set, implying that clinical management shifts from proactive neuroprotection to reactive damage control—managing intractable intracranial pressure to prevent lethal herniation.[17] The data overlay prominently displays the defining statistic of the study: 57.9% of all patients—the clear majority—arrived during this established damage phase. This finding is the visual centerpiece of the failed golden hour argument. It demonstrates that the typical TBI patient at this tertiary center does not present as an acute neurosurgical emergency with salvageable tissue, but rather as a sub-acute case with established, often irreversible, secondary pathology. Figure 6 concludes with an interpretive footer summarizing the intervention gap. It explicitly articulates the mismatch between biological urgency and logistical reality. It reiterates that because this pattern of extreme delay persisted across all three years of the study—independent of the dramatic fluctuations in traffic density caused by the pandemic—the primary barriers must be structural system II failures. These include inefficient inter-hospital referral hierarchies, scarcity of emergency transport resources, and delays in decision-making, rather than simple road congestion. Figure 6 ultimately serves as a powerful, evidence-based call for a fundamental restructuring of the pre-hospital trauma network, visualizing the human cost of time lost.[18]

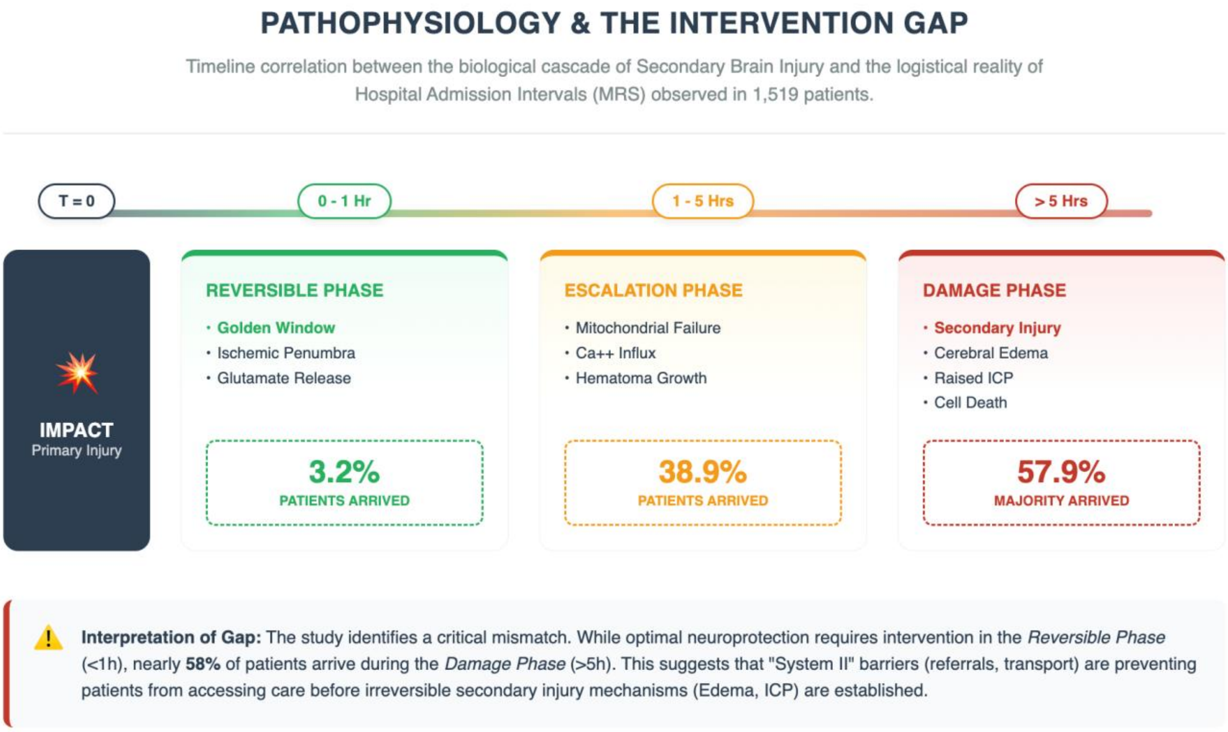

Figure 6. Pathophysiology and the intervention gap.

The most striking epidemiological finding of this study is the drastic 75% reduction in TBI cases in 2020, followed by a sharp rebound in 2021. This V-curve aligns perfectly with the implementation and subsequent relaxation of the PSBB protocols. In the context of injury prevention theory, specifically the Haddon matrix, this phenomenon demonstrates the overwhelming power of pre-event intervention through exposure reduction. By mandating stay-at-home orders, the government effectively removed the host (the motorcycle rider) from the environment (the road), thereby severing the chain of injury causation. The drop in RTI cases from 490 to 107 is statistically profound and corroborates the theory that in LMICs, where active safety measures (like advanced braking systems or strict lane enforcement) are evolving, the volume of trauma is linearly dependent on economic mobility. However, the rapid resurgence of cases in 2021 (n=705) serves as a cautionary tale. As society adapted to the new normal, risk-taking behaviors returned, arguably exacerbated by restriction fatigue and the economic necessity of travel. This rebound indicates that the safety gains of 2020 were transient and purely extrinsic, rather than a result of intrinsic systemic improvements in road safety culture. Perhaps the most clinically concerning finding of this investigation is the resistance of the Hospital Admission Interval to improvement. Intuitively, one might hypothesize that the empty roads of the 2020 lockdown would facilitate rapid transport, thereby increasing the proportion of patients arriving within the golden hour. However, our data categorically refutes this. Only 3.23% of patients arrived within the critical <1 hour window. The vast majority (over 40%) arrived between 5 and 12 hours post-injury.

From a neurosurgical pathophysiology perspective, this delay is critical. The golden hour concept is grounded in the timeline of secondary brain injury.[19] Following the primary mechanical insult, the brain undergoes a delayed cascade of deterioration involving glutamate excitotoxicity, mitochondrial failure, calcium influx, and oxidative stress. These processes often peak within hours of the initial insult. Immediate resuscitation and surgical decompression (e.g., for Epidural Hematoma) are vital to interrupt this cascade and preserve the penumbra—the salvageable brain tissue surrounding the core injury. A delay of 5-12 hours places the average patient well into the phase of established secondary injury. By this time, cerebral edema is likely escalating, and the therapeutic window for optimal recovery is closing. The fact that 17.44% of patients arrived after 12 hours is alarming. This suggests that for nearly one-fifth of the cohort, the opportunity for early neuroprotective intervention was lost before they even reached the tertiary center.

The persistence of these delays, even when traffic was negligible during the 2020 lockdown, suggests that the barriers to the golden hour in Indonesia are not merely logistical (traffic) but systemic. We propose that these delays are driven by system II failures, defined as inefficiencies in the referral and decision-making processes rather than physical transport speed. Three key factors likely contributed to the persistent delays during the pandemic: 1. Referral Chain Dysfunction: RSHS is a top-tier referral center. During the pandemic, lower-tier district hospitals (Type B and C) were frequently overwhelmed with COVID-19 containment and isolation protocols. This likely slowed the triage, stabilization, and transfer negotiation for non-COVID trauma patients. The administrative friction of transferring a patient likely increased, negating any time gained from clearer roads. 2. Psychological Barriers (The Second Pandemic): The fear of contracting COVID-19 in a hospital setting (nosocomial transmission) likely caused a behavioral shift. Patients with mild-to-moderate injuries (GCS 13-15), who constitute the majority of our cohort, may have hesitated to visit a COVID-19 referral center like RSHS until their symptoms worsened. This wait-and-see approach would push patients from the acute window into the >12 hour delayed category. 3. Transport Resource Scarcity: While roads were empty, the vehicles themselves were occupied. Ambulances were heavily repurposed for transporting infectious COVID-19 patients, potentially creating a scarcity of EMS resources for neurotrauma. This would force families to rely on private transport or wait longer for available ambulances, maintaining the delay interval.[20]

The study highlights a crucial divergence in injury mechanisms based on age, which became more relevant during the lockdown phases. While RTIs decreased, the persistence of falls in the pediatric (0-4 years) and geriatric (≥65 years) populations highlights a domestic transfer of risk. The dominance of falls (54.93%) in toddlers reflects the biomechanics of the developing skull. Children in this age group have a higher center of gravity relative to their height and thinner cranial tables, making them uniquely susceptible to linear fractures from low-height falls. The pandemic confinement likely increased exposure to household hazards (stairs, furniture) for longer durations, emphasizing the need for domestic safety education as part of future lockdown protocols. Similarly, the elderly suffered predominantly from falls (36%). In this demographic, the pathophysiology is complicated by cerebral atrophy. As the brain atrophies, the bridging veins traversing the subdural space are stretched and become fragile. Even minor domestic impacts can tear these veins, leading to Chronic Subdural Hematoma (cSDH). Furthermore, the isolation of the pandemic may have resulted in unobserved falls or delayed discovery of injured seniors living alone, further contributing to the admission delays observed.[17,18]

The overwhelming male predominance (78.4%) and the high incidence in the 15-24 age group (30.68%) underscore the immutable socio-economic drivers of TBI in Indonesia. Young males constitute the primary workforce and are the most frequent users of motorcycles. The kinetic energy transfer in motorcycle accidents is significantly higher than in falls, correlating with the high rates of Loss of Consciousness (60.17%) and the substantial number of severe injuries observed. This demographic is also biologically prone to risk-taking behaviors, as frontal lobe development continues into the mid-20s. This biological predisposition, combined with economic necessity, explains why the RTI volume rebounded so aggressively in 2021, the moment restrictions were lifted.

5. Conclusion

The COVID-19 pandemic and the subsequent PSBB restrictions in Indonesia created a distinct epidemiological signature in neurotrauma: a dramatic but temporary reduction in volume driven by decreased road traffic incidents. However, the most critical lesson lies in the failure of the golden hour. The lack of improvement in hospital arrival times, despite the unique condition of reduced traffic density, exposes deep-seated structural and behavioral barriers to emergency care in West Java. The persistence of admission delays exceeding 5 hours for the majority of patients indicates that the pre-hospital network—comprising the referral chain, ambulance availability, and public health decision-making—is the rate-limiting step in trauma survival, not just traffic congestion. Moving forward, improving TBI outcomes in Indonesia requires more than just road infrastructure projects. It demands a restructuring of the pre-hospital emergency network to ensure streamlined referrals, dedicated trauma transport lanes (Green Lanes) during public health crises, and aggressive public education on the urgency of head injuries to overcome hesitancy. Only by addressing these System II failures can we hope to bring the golden hour within reach for the Indonesian population.[19,20]

6. References

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