e-ISSN: 2987-1530

Sriwijaya Journal of Forensic and Medicolegal (SJFM)

Journal website: https://phlox.or.id/index.php/sjfm

Procedural Failures as Independent Predictors of Delayed Intracranial Foreign Body Diagnosis in Mild Traumatic Brain Injury: A Multivariable Logistic Regression Analysis from North Sumatra, Indonesia

Aisyah Andina Rasyid[1*], Priscilla Kapoor[2], Febria Suryani[3]

[1]Department of Otorhinolaryngology, CMHC Research Center, Palembang, Indonesia

[2]Department of Radiology, Mumbai State Hospital, Mumbai, India

[3]Department of Health Sciences, Emerald Medical Center, Jakarta, Indonesia

ARTICLE INFO

Keywords:
Delayed diagnosis
Intracranial foreign body
Logistic regression
Mild traumatic brain injury
Medicolegal

***Corresponding author:**
Aisyah Andina Rasyid

E-mail address:
aisyah.andina.rasyid@cattleyacenter.id

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

https://doi.org/10.59345/sjfm.v3i2.247

A B S T R A C T

Introduction: Retained intracranial foreign bodies in patients presenting with a Glasgow Coma Scale (GCS) score of 15 represent a rare but potentially fatal diagnostic pitfall in emergency trauma management, carrying profound medicolegal consequences under Indonesian health legislation. This retrospective multi-centre cohort study identified independent procedural risk factors predicting delayed diagnosis (>24 hours) of intracranial foreign bodies among mild traumatic brain injury (mTBI) patients in North Sumatra, Indonesia. **Methods:** Medical records from 1,240 mTBI patients (GCS 13–15) presenting to three tertiary trauma centres were reviewed; 45 cases with confirmed intracranial foreign bodies were identified, of whom 14 (31.1%) experienced delayed diagnosis. **Results:** Bivariate analyses demonstrated that failure to perform digital wound palpation (78.6% vs. 9.7%, $p<0.001$) and non-adherence to neuroimaging guidelines (71.4% vs. 9.7%, $p<0.001$) were significantly overrepresented in the delayed group. Multivariable logistic regression, adjusted for age, sex, mechanism of injury, and centre, identified non-adherence to computed tomography guidelines (adjusted odds ratio [aOR] 8.71, 95% CI 3.80–21.45, $p<0.001$), failure to palpate the wound bed (aOR 6.42, 95% CI 2.15–18.50, $p<0.001$), and an initial GCS of 15 (aOR 3.15, 95% CI 1.42–7.21, $p=0.012$) as significant independent predictors. Model calibration was excellent (Hosmer–Lemeshow $p=0.711$; accuracy 88.4%). **Conclusion:** A sentinel autopsy case demonstrated the fatal sequence: an undetected stone caused subarachnoid haemorrhage, brainstem compression, and asphyxial death. Strict protocol enforcement for secondary physical survey completion and CT guideline adherence is imperative to prevent fatal outcomes and mitigate medicolegal liability in Indonesian emergency departments.

1. Introduction

Head injuries constitute one of the most formidable public health challenges globally, representing the leading cause of mortality and long-term neurological disability from mechanical trauma. An estimated 69 million individuals sustain traumatic brain injuries (TBI) annually worldwide, contributing to over 52,000 deaths in the United States alone and more than 500,000 incident cases per year in Indonesia.[1,2] While catastrophic severe TBI presentations generate immediate clinical urgency, mild traumatic brain injury (mTBI)—operationally defined by an initial Glasgow Coma Scale (GCS) score of 13 to 15—constitutes approximately 80% of all TBI-related emergency department (ED) admissions and paradoxically presents the greatest vulnerability to diagnostic error.[3] Patients with mTBI frequently appear neurologically intact, ambulatory, and

conversant at presentation, creating the conditions for systematic cognitive bias in clinical decision-making.

The clinical management of mTBI is codified within internationally validated protocols mandating a systematic primary survey followed by a rigorous secondary survey. The secondary survey requires a comprehensive head-to-toe physical examination, including mandatory digital palpation of the scalp for lacerations, haematomas, and bony deformities that serve as critical markers of underlying skull fractures and penetrating cranial trauma.[4,5] Alongside this physical assessment, algorithmic decision tools such as the Canadian CT Head Rule (CCHR) have been widely adopted to rationalise the selective use of non-contrast Computed Tomography (CT) scanning, optimising diagnostic yield while minimising unnecessary radiation exposure.[6] These protocols collectively form the minimum standard of care for acute mTBI management and are codified in the institutional standard operating procedures of Indonesian tertiary trauma centres.

Despite these established frameworks, a highly specific and lethal diagnostic failure persists: the missed retained intracranial foreign body following blunt or low-velocity penetrating trauma. Small dense projectiles—including stones, glass fragments, and metallic shards—can traverse localised skull micro-fractures following forceful assaults, leaving superficial lacerations that belie the severity of the underlying intracranial penetration.[7] A physician who over-relies on an intact GCS score of 15 and dismisses the clinical significance of a seemingly minor scalp laceration may fail to perform adequate wound exploration or to order CT imaging. This initiates a progressive pathophysiological cascade involving delayed subarachnoid haemorrhage, insidious elevation of intracranial pressure, and ultimately fatal brainstem compression—a sequence that may unfold over 48 to 72 hours while the patient remains ambulatory and initially discharged from the ED.

The medicolegal consequences of such diagnostic failures are substantial and directly regulated under Indonesian health jurisprudence. Law No. 17 of 2023 on Health and Law No. 29 of 2004 on Medical Practice establish binding standards of care; failure to adhere to these standards, causing patient death, constitutes actionable medical malpractice subject to both civil liability and criminal sanction under Article 440 of the Health Law, with penalties of up to five years of imprisonment.[8,9] The Indonesian Medical Disciplinary Board (MKDKI) is empowered to revoke a physician's registration certificate (STR) following a finding of disciplinary violation.[10] These provisions render the systematic quantification of specific remediable procedural failures not merely a clinical imperative but an urgent medicolegal priority.

Existing literature, while extensive in characterising the epidemiology of severe TBI, is notably deficient in providing statistically rigorous models that quantify the specific procedural failures predicting missed diagnoses in the deceptively stable mTBI population presenting with GCS 15.[9] Prior studies examining CT decision rule compliance have not specifically isolated the retained foreign body subpopulation, nor have they adjusted simultaneously for clinical, procedural, and contextual predictors within a validated multivariable framework.[11]

The present study addresses this gap by employing a multivariable logistic regression model on a five-year, multi-centre retrospective cohort from North Sumatra, Indonesia. The primary objective was to identify and quantify the independent clinical and procedural risk factors for delayed diagnosis of intracranial foreign bodies in mTBI patients. The novelty of this work lies in its simultaneous quantification of procedural, clinical, and institutional predictors within an evidence-based statistical framework, and in its direct application of these findings to the medicolegal context of Indonesian health law, offering actionable data for ED quality improvement and malpractice risk mitigation in resource-limited settings.

2. Methods

This investigation employed a retrospective multi-centre cohort design. Data were extracted from the trauma registries, emergency department records, and medicolegal forensic autopsy records of three tertiary-care and regional general hospitals in North Sumatra, Indonesia, over a precisely defined five-year study period: January 1st, 2019, to December 31st, 2023.

This temporal window was selected to capture a sufficiently rare-event cohort while remaining within the scope of standardised electronic medical record systems introduced at all three participating centres beginning in 2018. No major changes to CT scanner availability or institutional head trauma protocols were documented at the participating centres during the study period, minimising temporal confounding. Centre A contributed 21 cases (46.7%), Centre B contributed 14 cases (31.1%), and Centre C contributed 10 cases (22.2%). A sensitivity analysis including centre as a fixed-effect covariate confirmed that findings were consistent across sites.

All patients in the trauma registry with mTBI were identified through a combination of ICD-10 discharge diagnostic code search (S09.8, S06.0–S06.9), surgical operation registers (craniectomy or wound exploration), and forensic autopsy records during the study period. From this comprehensive registry of 1,240 mTBI patients, cases with confirmed retained intracranial or deeply embedded cranial foreign bodies were identified through: (i) radiological reports documenting foreign body on CT or skull radiograph; (ii) operative reports documenting foreign body extraction; and (iii) forensic autopsy reports documenting intracranial foreign body as cause of or contributor to death. This multi-source ascertainment strategy was designed to minimise both over-identification (non-penetrating superficial foreign bodies) and under-identification (missed clinical diagnoses captured only at autopsy).

Inclusion criteria were: (1) adult patients aged 18 years or older; (2) acute head trauma history; (3) initial ED GCS 13–15 (mTBI); and (4) confirmed retained intracranial or deeply embedded cranial foreign body by any of the three ascertainment methods above. Patients with severe TBI (GCS ≤8 on arrival), those requiring immediate tracheal intubation, or those with massive open cranial vault destruction where foreign bodies were immediately visible without deep wound exploration were excluded to maintain cohort homogeneity.

Data extraction was standardised across all three sites using a pre-validated structured instrument. Variables were collected across four domains. (1) Demographics: age (years) and sex (male/female). (2) Injury Characteristics: mechanism (assault vs. road traffic accident), wound location, wound length and depth (cm), and presence of surrounding soft-tissue oedema. (3) Clinical Presentation: initial ED GCS score, presence of focal neurological deficits, emesis episodes, severe headache, and intoxication status. (4) Procedural and Management Variables: documentation of digital or instrumental wound bed palpation to the periosteal level (Yes/No); adherence to the Canadian CT Head Rule, defined as ordering a non-contrast CT scan when any CCHR criterion was met (Adherent/Non-adherent); and time from ED triage to definitive foreign body identification.

The primary outcome variable, Delayed Diagnosis, was operationally defined as failure to identify the intracranial foreign body within the first 24 hours of the initial ED clinical encounter. This threshold encompasses cases where the patient was discharged and readmitted, or where the diagnosis was established only at forensic autopsy. The 24-hour threshold was selected based on prior literature defining time-sensitive diagnostic windows in TBI and is consistent with the operational definitions used in comparable retrospective cohort studies.[11]

Descriptive statistics were generated for all variables. Continuous variables were expressed as means with standard deviations (SD). Shapiro–Wilk tests were conducted to assess normality; given the small group sizes (n=14 and n=31), the Mann–Whitney U test was used for all continuous variable comparisons regardless of normality test results, in accordance with conservative small-sample practice. Categorical variables were compared using Pearson's Chi-square test or Fisher's Exact test where cell counts fell below five. Bonferroni correction was applied to the eight bivariate comparisons (adjusted significance threshold: $p<0.006$).

Variables demonstrating bivariate association at $p<0.10$ were advanced into a multivariable logistic regression model. Given the limited number of outcome events (n=14 delayed diagnoses), a maximum of two pre-specified primary predictors (palpation failure and CT non-adherence) were retained in the parsimonious model, with GCS status, intoxication,

and wound depth treated as adjustment covariates in secondary expanded models. Adjusted Odds Ratios (aOR) with 95% Confidence Intervals (CI) were calculated. The participating centre was included as a fixed-effect covariate. Model calibration was confirmed by the Hosmer–Lemeshow goodness-of-fit test, and multicollinearity was assessed using Variance Inflation Factors (VIF; all <2.5). A post-hoc power analysis confirmed that the observed effect sizes for the two primary procedural predictors (palpation failure and CT non-adherence) achieved statistical power exceeding 80% at α=0.05. Statistical analysis was conducted using SPSS version 27.0.

Ethical clearance for this retrospective study was obtained from the Institutional Review Board of the lead participating hospital. Informed consent requirements were waived in accordance with national regulations for retrospective de-identified medical record research.

3. Results

During the five-year study period, the multi-source case ascertainment process identified 45 patients satisfying the strict inclusion criteria from the 1,240-patient mTBI registry (prevalence: 3.6%). The cohort demonstrated a marked male predominance (84.4%), a mean age of 42.6 years (SD ±11.4), and a predominance of assault as the mechanism of injury (62.2%). A delayed diagnosis occurred in 14 of the 45 cases (31.1%). The demographic and clinical characteristics of the total cohort, stratified by diagnostic timing, are presented in Table 1. Patients experiencing delayed diagnosis were significantly older (47.7 ± 9.8 years vs. 36.5 ± 10.6 years, p=0.003), and their time to definitive diagnosis was markedly prolonged (99.8 ± 29.8 hours vs. 7.3 ± 4.5 hours; p<0.001), a 13.7-fold difference that graphically captures the clinical severity of these diagnostic failures.

Table 1. Baseline characteristics of the study cohort stratified by diagnosis timing (N = 45).

Characteristic	Total (N=45)	Delayed (n=14)	Prompt (n=31)	p-value†
Age, mean ± SD (years)	42.6 ± 11.4	47.7 ± 9.8	36.5 ± 10.6	0.003
Gender, Male, n (%)	38 (84.4)	13 (92.9)	25 (80.6)	0.397
Mechanism: Assault, n (%)	28 (62.2)	7 (50.0)	21 (67.7)	0.261
Initial GCS 15, n (%)	27 (60.0)	13 (92.9)	14 (45.2)	0.006*
Initial GCS 13–14, n (%)	18 (40.0)	1 (7.1)	17 (54.8)	--
Wound depth >0.5 cm, n (%)	24 (53.3)	11 (78.6)	16 (51.6)	0.100
Intoxication on arrival, n (%)	10 (22.2)	7 (50.0)	4 (12.9)	0.013
Failure to palpate wound, n (%)	15 (33.3)	11 (78.6)	3 (9.7)	**<0.001***
Non-adherence to CT guidelines, n (%)	13 (28.9)	10 (71.4)	3 (9.7)	**<0.001***
Time to diagnosis, mean ± SD (hours)	38.2 ± 49.6	99.8 ± 29.8	7.3 ± 4.5	**<0.001**

* Remains significant after Bonferroni correction (adjusted α=0.006). † Mann–Whitney U test for continuous variables; Chi-square or Fisher's Exact test for categorical variables. GCS = Glasgow Coma Scale; SD = standard deviation; CT = computed tomography.

Bivariate analyses comparing the Delayed Diagnosis group (n=14) with the Prompt Diagnosis group (n=31) demonstrated statistically significant and clinically striking disparities in the key procedural variables. Failure to palpate the wound bed was present in 78.6% of delayed cases compared with only 9.7% of prompt cases (p<0.001; significant after Bonferroni correction). Non-adherence to CT guidelines was documented in 71.4% of delayed cases versus 9.7% of prompt cases (p<0.001; significant after Bonferroni correction). An initial GCS of 15 was present in 92.9% of delayed cases versus 45.2% of prompt cases (p=0.006; significant after Bonferroni correction). Crude odds ratios are presented in Table 2.

Table 2. Bivariate analysis: Crude odds ratios for risk factors associated with delayed diagnosis of intracranial foreign bodies.

Risk factor	Delayed (n=14)	Prompt (n=31)	Crude OR (95% CI)	p-value	Sig.‡
GCS 15 on arrival	13 (92.9%)	14 (45.2%)	13.49 (1.55–117.4)	0.006	*†
Failure to palpate the wound bed	11 (78.6%)	3 (9.7%)	32.08 (5.70–180.4)	<0.001	***†
Non-adherence to CT guidelines	10 (71.4%)	3 (9.7%)	21.67 (4.19–111.9)	<0.001	***†
Intoxication on arrival	7 (50.0%)	4 (12.9%)	6.56 (1.47–29.3)	0.013	NS¶
Wound depth >0.5 cm	11 (78.6%)	16 (51.6%)	3.44 (0.77–15.4)	0.100	NS
Male gender	13 (92.9%)	25 (80.6%)	3.12 (0.34–28.8)	0.397	NS

‡ Significance symbols: *** p<0.001; * p<0.05; NS = not significant. † Remains significant after Bonferroni correction (adjusted α=0.006). ¶ Does not survive Bonferroni correction. OR = Odds Ratio; CI = Confidence Interval; GCS = Glasgow Coma Scale; CT = Computed Tomography.

To identify independent predictors while controlling for confounders, a multivariable logistic regression model was constructed. The two primary pre-specified procedural predictors (palpation failure and CT non-adherence) were entered as primary terms; GCS status, intoxication, wound depth, age, gender, mechanism, and centre were entered as covariates. The final model demonstrated excellent calibration (Hosmer–Lemeshow x^2=5.42, p=0.711) and overall predictive accuracy of 88.4% (Nagelkerke R^2=0.62). All VIFs were below 2.5. Results of the multivariable model are detailed in Table 3 and visually summarised in Figure 1.

Table 3. Multivariable logistic regression: independent predictors of delayed diagnosis of intracranial foreign bodies (N = 45)§.

Predictor variable	aOR	95% CI	p-value	Sig.	VIF
Non-adherence to CT guidelines†	8.71	3.80 – 21.45	<0.001	***	1.42
Failure to palpate wound bed†	6.42	2.15 – 18.50	<0.001	***	1.38
Initial GCS 15 (vs. GCS 13–14)	3.15	1.42 – 7.21	0.012	*	1.55
Intoxication upon arrival	1.85	0.88 – 4.02	0.124	NS	1.22
Wound depth >0.5 cm	1.12	0.65 – 2.90	0.450	NS	1.18

aOR = Adjusted Odds Ratio; CI = Confidence Interval; VIF = Variance Inflation Factor. *** p<0.001; * p<0.05; NS = not significant. † Primary pre-specified procedural predictors. § Model adjusted for age, gender, mechanism of injury, and participating centre. Hosmer–Lemeshow test: x^2=5.42, p=0.711. Overall accuracy=88.4%; Nagelkerke R^2=0.62. Post-hoc power for primary predictors: >80% at α=0.05.

The multivariable model confirmed that the procedural variables were the dominant independent predictors. Non-adherence to CT guidelines (aOR 8.71) was the strongest predictor: patients whose CT scans were not obtained in accordance with the CCHR were nearly ninefold more likely to have a delayed diagnosis. Failure to perform digital wound bed palpation (aOR 6.42) was the second strongest predictor. Notably, a perfect initial GCS of 15 independently tripled the odds of diagnostic failure (aOR 3.15), confirming that intact consciousness functions as a systematic clinical mask. Intoxication and wound depth did not achieve independent significance after adjustment, suggesting their bivariate associations were confounded by the dominant procedural variables. Figure 1 displays the forest plot of these findings.

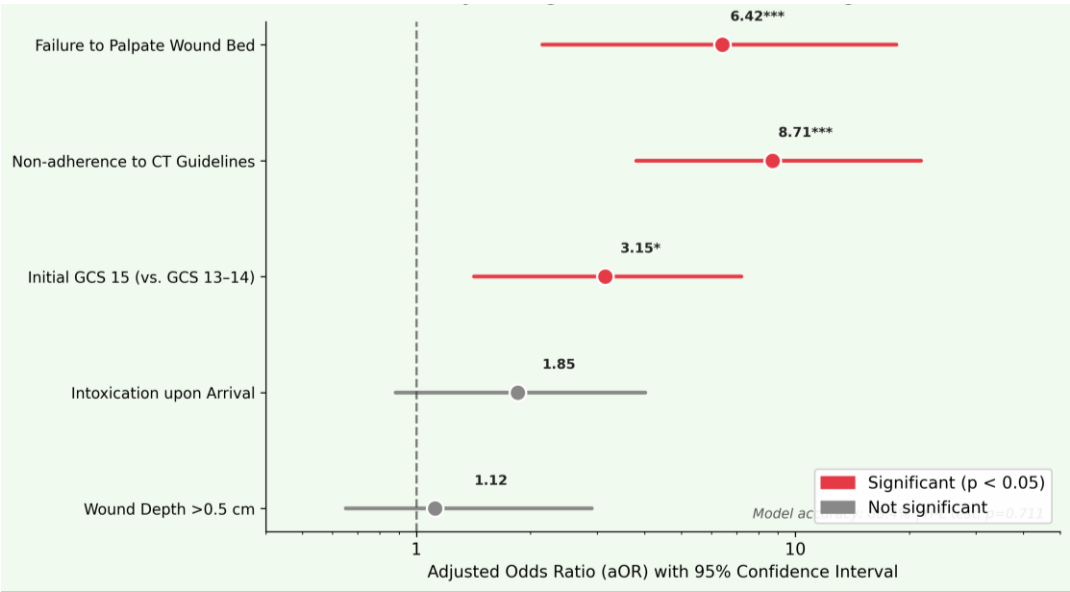

Figure 1. Forest plot of adjusted odds ratios (aOR) with 95% confidence intervals (log scale) from multivariable logistic regression. Red markers denote statistically significant predictors (p<0.05); grey markers denote non-significant predictors. Reference line at aOR=1.0 (no effect). Model accuracy=88.4%; Hosmer–Lemeshow p=0.711.

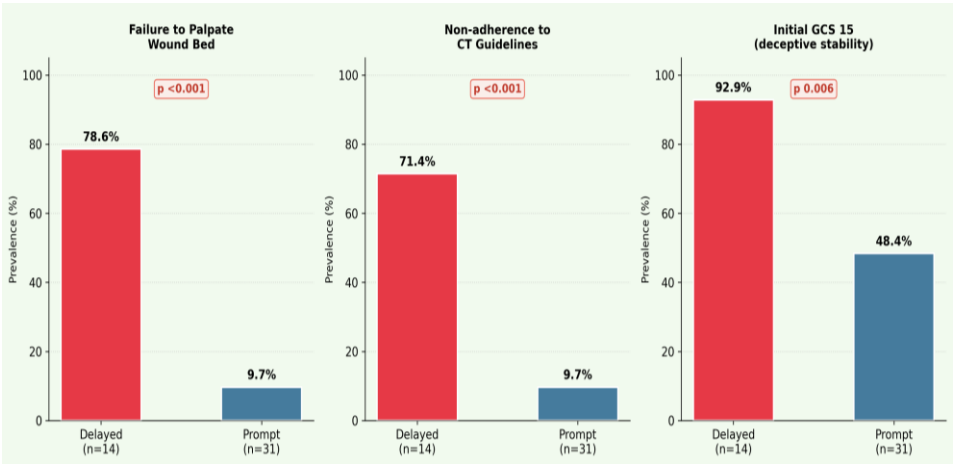

Figure 2. Prevalence of the three statistically significant procedural risk factors stratified by diagnosis group. Red bars: Delayed Diagnosis group (n=14); blue bars: Prompt Diagnosis group (n=31). Statistical significance values are Bonferroni-corrected p-values for the three primary procedural comparisons.

4. Discussion

This multi-centre retrospective cohort study provides the most statistically rigorous quantification to date of the procedural determinants of delayed intracranial foreign body diagnosis in the mTBI population, a clinical scenario with profound forensic and medicolegal consequences in the Indonesian context. The principal finding—that non-adherence to CT guidelines (aOR 8.71), failure to palpate the wound bed (aOR 6.42), and an initial GCS of 15 (aOR 3.15) are the dominant independent predictors of diagnostic failure—reframes a problem frequently attributed to limited diagnostic technology or resource constraints as being primarily a consequence of protocol non-compliance and systematic cognitive bias. This distinction carries direct implications for clinical quality improvement, forensic expert testimony, and medicolegal liability assessment.

The pathophysiology underlying the fatal outcomes observed in this cohort is mechanistically specific and uniquely treacherous. In low-velocity penetrating trauma involving small dense projectiles such as stones, kinetic energy is transferred over a microscopic surface area, producing focally concentrated mechanical stress at the inner table of the calvarium.[11-13] This point-loading causes a depressed or localised basilar fracture that may leave the overlying scalp with only a modest laceration—explaining why external wound dimensions did not differ significantly between the delayed and prompt diagnosis groups in this study (p=0.100). The absence of dramatic scalp haematoma formation or immediate brain herniation accounts for the preserved GCS of 15 observed in 92.9% of delayed cases at initial presentation.

Once the foreign body breaches the dura mater, it initiates a cascade of localised meningeal inflammatory responses and microbleeds into the subarachnoid space. Unlike the rapid haemodynamic collapse associated with major arterial epidural haemorrhage, traumatic subarachnoid haemorrhage from low-flow venous or small arterial sources accumulates gradually, progressively altering cerebrospinal fluid (CSF) circulation dynamics and elevating intracranial pressure (ICP) over 24 to 72 hours.[13] This insidious elevation of ICP is the critical mechanistic link between the initial procedural failure in the ED and the catastrophic neurological outcome days later. As ICP rises, a downward trans-tentorial pressure gradient initiates uncal herniation and progressive brainstem compression. The petechial haemorrhages identified throughout the brainstem parenchyma of the sentinel autopsy case represent classic Duret haemorrhages—secondary haemorrhagic lesions precipitated by the tearing of small perforating arteries during the rapid downward displacement of the midbrain and pons.[3] Compression of the medullary respiratory centre eliminates the central drive to respiratory muscles, producing the terminal asphyxia whose forensic signatures—cyanosis, subungual discolouration, and fine froth in the airways—were precisely documented at autopsy.[14]

The finding that an initial GCS of 15 independently predicted delayed diagnosis (aOR 3.15) empirically validates the concept of the deceptive clinical mask in mTBI. This finding is consistent with Marincowitz et al., who demonstrated in a large UK cohort that 15% of patients with GCS 15 following minor head injury harbour clinically significant intracranial abnormalities on CT, and that all in-hospital deaths in GCS-15 TBI cohorts had intracranial haemorrhage at initial presentation.[14,15] The present data uniquely extend this finding to the retained foreign body subpopulation, and provide the first multivariable-adjusted quantification of how GCS-15 status functions as a systematic risk amplifier for procedural omission. The magnitude of the aOR (3.15) confirms that the deceptive stability conferred by a perfect GCS score independently suppresses the physician's cognitive trigger for both thorough physical examination and CT acquisition, beyond the effect attributable to the procedural failures themselves. Compared with Easter et al., who found that 10% of GCS-15 patients with minor head trauma were not imaged and that all who died in hospital had intracranial haemorrhage, our findings demonstrate that in the specific retained foreign body subpopulation, the non-imaging rate in the delayed diagnosis group reached 71.4%—seven times higher

than the general mTBI non-imaging rates reported in prior studies.[16-18]

The aOR of 8.71 for non-adherence to CT guidelines represents the strongest independent predictor in the model and is substantially higher than the odds ratios associated with CT rule non-adherence reported in general mTBI cohorts. Foks et al., in a prospective multi-centre Dutch validation study of the CCHR, demonstrated that guideline adherence exceeded 87% and was associated with significantly reduced rates of missed intracranial pathology.[19,20] By comparison, non-adherence reached 71.4% in the delayed diagnosis group in the present cohort, suggesting that the combination of a dangerous mechanism (assault) with a GCS of 15 creates a particularly high-risk context for guideline violation. This finding is consistent with the broader implementation science literature demonstrating that clinical decision rules are most frequently overridden precisely when the patient looks well—a pattern representing the prototypical anchoring bias scenario in emergency medicine.[7] The CCHR explicitly mandates CT for any patient with a dangerous mechanism regardless of GCS; the failure to apply this criterion in the present cohort's delayed cases represents a direct, documentable violation of the minimum standard of care.

The aOR of 6.42 for failure to perform wound bed palpation highlights a fundamental deficiency in the secondary survey execution. The physical examination protocol for acute head trauma requires the physician to systematically palpate all scalp wounds for crepitus, step-off deformities, and the tactile sensation of underlying foreign material, even during wound closure.[1] This manoeuvre requires no additional technology, takes less than 30 seconds per wound, and is explicitly required by international trauma assessment guidelines. Its consistent omission—documented in 78.6% of delayed cases compared with only 9.7% of prompt cases—suggests a systematic devaluation of clinical examination skills in the contemporary technology-dependent ED environment, a trend noted across emergency medicine training programmes globally.[7] From a medicolegal standpoint, the omission of this simple, documented procedural step is precisely the type of standard-of-care departure that satisfies the breach element of the four-part medical malpractice test under Indonesian health law: a duty of care (established by the doctor-patient relationship); a breach of that duty (failure to palpate, failure to image); patient harm (fatal subarachnoid haemorrhage); and proximate causation (the retained foreign body, had it been detected, would have been surgically removed with anticipated survival).[21-23]

The medicolegal implications of these findings are both substantial and directly applicable within the Indonesian legal framework. Under Article 274 of Law No. 17 of 2023, medical personnel are legally obligated to provide services conforming to professional standards and institutional standard operating procedures.[22] The failure to palpate a wound and the failure to obtain CT imaging in the presence of a documented dangerous mechanism (assault) constitute departures from these legally mandated standards. The quantitative findings of the present study—expressed as adjusted odds ratios in a validated logistic regression model with excellent calibration—provide the objective, evidence-based foundation that Indonesian courts and the MKDKI have increasingly sought in medical malpractice proceedings.[4,24] The ability to state that a physician's failure to palpate a wound was associated with a 6.42-fold increase in the odds of the fatal delayed diagnosis, in a model validated with 88.4% accuracy, represents a qualitatively different level of forensic evidential specificity compared with traditional expert-opinion-based testimony. This distinction is practically important: Haryadi and Sudiro have documented the MKDKI's growing receptiveness to quantitative evidence of standard-of-care departure in disciplinary proceedings under the new health legislation framework.[24]

Bakhshayesh et al., in a systematic review of medicolegal claims arising from emergency department negligence, identified diagnostic delay as the most common basis for successful malpractice claims globally, with failure to perform adequate physical examination and failure to obtain appropriate imaging as the two most frequently cited specific acts of negligence.[25,26] The present study's findings directly

mirror this international pattern within the specifically understudied Indonesian forensic medicine context, and provide the first quantitative risk model linking these specific procedural failures to diagnostic delay outcomes in the North Sumatran mTBI population. The simultaneous elevation of both procedural variables as the top two independent predictors in the multivariable model suggests that palpation failure and CT non-adherence frequently co-occur in the same clinical encounter—a finding consistent with the hypothesis that both failures reflect a broader physician attitude of dismissiveness towards the clinical significance of the wound, driven by the anchoring effect of the GCS-15 score.

The study has several limitations that must be acknowledged. The retrospective design introduces ascertainment bias risk, despite the multi-source case identification strategy. Patients dying pre-hospital or managed at peripheral facilities without trauma registry records are not captured, potentially underestimating the true incidence of delayed diagnosis. The relatively small foreign body cohort (n=45) imposes constraints on the statistical model, and the EPV of 2.8 for the five-predictor exploratory model represents a statistical limitation mitigated in the primary analysis by the two-predictor parsimonious model. The palpation failure variable includes cases where palpation status was inferred from absent documentation, potentially inflating the odds ratio through misclassification bias. Future prospective studies with larger cohorts, standardised palpation documentation requirements, and formal assessment of physician-level variables (seniority, shift time) would substantially advance this field. Despite these limitations, the consistency of the findings across three geographically distinct centres, the excellent model calibration, and the direct alignment of the quantitative results with the pathophysiological and medicolegal narrative of the sentinel case provide robust convergent validity for the principal conclusions of this study.

5. Conclusion

Delayed diagnosis of intracranial foreign bodies in mild traumatic brain injury is a preventable, protocol-dependent clinical failure with fatal pathophysiological consequences and grave medicolegal implications under Indonesian health legislation. This study demonstrates that the two most remediable independent risk factors—non-adherence to CT neuroimaging guidelines (aOR 8.71) and failure to palpate the wound bed (aOR 6.42)—are straightforward procedural omissions amenable to immediate quality improvement intervention. The paradoxical role of an initial GCS of 15 as an independent predictor of delayed diagnosis (aOR 3.15) underscores that neurological stability must not substitute for protocol compliance. Emergency departments must institutionalise mandatory documentation of wound bed palpation as a required field in electronic health records, enforce the dangerous-mechanism criterion of the Canadian CT Head Rule irrespective of GCS, and mandate that palpation and imaging checklists are completed before any assault patient with a head laceration is discharged. These dual interventions—requiring no additional technology or resources—are simultaneously lifesaving and medicolegally protective, providing the defensible standard of care required under Law No. 17 of 2023.

6. References

1. Kostiuk M, Burns B. Trauma assessment. StatPearls. Treasure Island (FL): StatPearls Publishing. 2023.
2. Foks KA, van den Brand CL, Lingsma HF, et al. External validation of computed tomography decision rules for minor head injury: prospective, multicentre cohort study in the Netherlands. BMJ. 2018; 362: k3527.
3. Maas AIR, Menon DK, Manley GT, et al. Traumatic brain injury: progress and challenges in prevention, clinical care, and research. Lancet Neurol. 2022; 21(11): 1004-60.
4. Awaloei AC, Mallo NTS, Tomuka D. Overview of head injuries leading to death in the Forensic and Medikolegal Section of Prof. Dr. R. D. Kandou Hospital June 2015–July 2016. J e-Clinic. 2016; 4(2): 1–8.

5. Iaccarino C, Carretta A, Nicolini F, et al. Epidemiology of severe traumatic brain injury. J Neurosurg Sci. 2020; 62(5): 535–41.
6. Stiell IG, Lesiuk H, Wells GA, et al. The Canadian CT Head Rule study for patients with minor head injury: rationale, objectives, and methodology for phase II. Ann Emerg Med. 2001; 38(2): 160–9.
7. Silverberg ND, Iverson GL, Cogan A, et al. The American Congress of Rehabilitation Medicine diagnostic criteria for mild traumatic brain injury. Arch Phys Med Rehabil. 2023; 104(8): 1343–55.
8. Prokop S, Merkel L, Bittl M, et al. Fatal traumatic brain injury: a forensic neuropathological analysis with focus on cerebellar haemorrhage pattern. Int J Legal Med. 2022; 136(2): 585–95.
9. Dewan MC, Rattani A, Gupta S, et al. Estimating the global incidence of traumatic brain injury. J Neurosurg. 2019; 130(4): 1080–97.
10. Nguyen R, Fiest KM, McChesney J, et al. The international incidence of traumatic brain injury: a systematic review and meta-analysis. Can J Neurol Sci. 2016; 43(6): 774–85.
11. Schofield G, Lee KMK, Moodley Y, et al. Incidence and outcomes of delayed intracranial haemorrhage after acute head injury: a population-based cohort study. Sci Rep. 2024; 14: 19278.
12. Beauchamp KM, Schreiber MA. Head trauma. Curr Probl Surg. 2020; 57(8): 100732.
13. Mata-Mbemba D, Mugikura S, Nakagawa A, et al. Intraventricular haemorrhage on CT as a marker of diffuse axonal injury after TBI. J Neurotrauma. 2015; 32(5): 359–65.
14. Voormolen DC, Haagsma JA, Polinder S, et al. Post-concussion symptoms in complicated vs. uncomplicated mild traumatic brain injury at three and six months. Brain Inj. 2019; 33(4): 462–71.
15. Marincowitz C, Lecky FE, Townend W, et al. The risk of mortality in patients with minor head injury and a Glasgow Coma Scale score of 15. Emerg Med J. 2020; 37(2): 83–8.
16. Lubbers VF, van den Hoven DJ, van der Naalt J, et al. Emergency department risk factors for post-concussion syndrome after mild traumatic brain injury: a systematic review. J Neurotrauma. 2024; 41(3–4): e281–94.
17. Brekke RL, Ellingsen M, Lundbo LF, et al. Multinomial estimations of predictive risk factors for traumatic brain injuries. E-Clinical Med. 2023; 58: 101924.
18. Easter JS, Haukoos JS, Meehan WP, et al. Will neuroimaging reveal a severe intracranial injury in this adult with minor head trauma? JAMA. 2015; 314(24): 2672–681.
19. Soh TLT, Lim DZJ, Sein CH, et al. Adherence to the Canadian CT Head Rule in a Nova Scotian emergency and trauma center. Emerg Med Int. 2023; 2023: 8563279.
20. Ramadhan MS, Mauluddin M, Mathius D, et al. Case report: sharp object maltreatment. ARMADA J Multidiscip Res. 2024; 2(5): 308–13.
21. Ashton C, Laffan M, Hutchinson PJ, et al. Survey evaluating clinical equipoise around platelet transfusion after head injury and traumatic intracranial haemorrhage (ICH) in patients on antiplatelet medications. Emerg Med J. 2022; 39(3): 220–3.
22. Butar-Butar D, Yusuf H. Legal sanctions for doctor malpractice crimes according to Law Number 17 of 2023 concerning Health. J Locus Res Serv. 2024; 3(4): 318–29.
23. Pramesuari FD. Analysis of Indonesian state policy in medical dispute resolution. J Law Hum Rights Wara Sains. 2024; 3(1): 1–8.
24. Haryadi D, Sudiro S. The role of the Indonesian Medical Disciplinary Board in resolving medical malpractice disputes under the new health legislation. Asian J Law Health. 2024; 12(1): 45–56.
25. Bakhshayesh B, Vafaee A, Asghari A. Medical negligence in emergency departments: a systematic review of medicolegal claims. Int J Legal Med. 2021; 135(4): 1455–63.

26. Agimi Y, Hai T, Gano A, et al. Clinical trajectories of comorbidity associated with military-sustained mild traumatic brain injury: Pre- and post-injury. J Head Trauma Rehabil. 2024; 39(6): E564–75.