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Traumatic Brain Injury at Bouaké University Hospital, Côte d'Ivoire: A Case-Mix-Adjusted Comparison of Two Consecutive Hospital Cohorts

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Abstract

➢ *Background.*

In sub-Saharan Africa, motorised two-wheeler transport has expanded faster than injury prevention and trauma-care capacity. Temporal changes in the profile and outcomes of traumatic brain injury (TBI) within a single referral centre remain poorly documented in sub-Saharan Africa, and crude mortality is often compared between periods without accounting for differences in case-mix.

➢ *Objective.*

The primary objective was to assess whether risk-adjusted in-hospital mortality differed between two consecutive hospital cohorts. Secondary, descriptive analyses compared epidemiology, admission severity, therapeutic activity and functional outcome. We hypothesised that any rise in crude mortality would be principally attributable to a more severe case-mix rather than to deteriorating care.

➢ *Methods.*

Single-centre observational comparison of two consecutive hospital cohorts of patients with traumatic brain injury: a historical cohort (2016–2021; n=594) reconstructed from the departmental database, and a recent prospectively documented cohort (2025–2026; n=772). Categorical variables were compared by chi-square/Fisher tests and continuous variables by the Mann–Whitney test; analyses were exploratory and p-values interpreted cautiously. Because the two periods differed in documentation completeness, variables were pre-classified, before any comparison, as ascertainment-robust or ascertainment-sensitive. The primary mortality model adjusted for pre-specified, ascertainment-robust covariates (age, sex, Glasgow Coma Scale [GCS], road-traffic crash as mechanism); a sensitivity model added anisocoria.

➢ *Results.*

The core demographic characteristics remained stable between periods (median age 30 years; male predominance). The distribution of injury mechanisms shifted toward a greater predominance of motorisation-related road-traffic injuries: road-traffic crashes rose from 75.3% to 89.4% and motorised two-wheeler involvement from 68.5% to 77.1%, with emerging three-wheeler injuries, while falls and assaults declined (all $p<0.001$). Documented helmet use among two-wheeler users remained very low and unchanged (5.6% vs 5.2%). The recent cohort had greater neurological severity (median GCS 13 in the recent vs 14 in the historical cohort; severe TBI 7.9% vs 1.3%; $p<0.001$) and higher crude mortality (4.7% vs 2.0%; absolute difference 2.6 percentage points, 95% CI 0.8–4.5; $p=0.009$). After case-mix adjustment, no statistically significant difference in mortality remained between periods (adjusted OR 1.23, 95% CI 0.60–2.52, $p=0.57$), GCS being the dominant determinant (OR 0.63 per point, $p<0.001$); the model showed good discrimination (AUC 0.78), the Hosmer–Lemeshow test revealing no major calibration defect ($p=0.47$), and findings were unchanged in the prespecified sensitivity analysis (OR 1.20, 95% CI

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0.58–2.50). Stratum-specific mortality was comparable for mild (1.1% vs 1.2%) and moderate (4.3% vs 5.4%) TBI. Large apparent increases in CT-documented lesions and surgical activity coincided with implausibly large increases in routinely recorded acute signs (e.g., anisocoria 0.2%→10.5%); these are reported descriptively only, as they are mainly compatible with more complete ascertainment in the recent period rather than with a real change in clinical profile.

➢ *Conclusion.*

Across two consecutive periods, the profile of admitted patients shifted toward greater initial neurological severity (as assessed by the GCS) and toward motorisation-related injuries, with a rise in crude mortality. This rise was principally attributable to differences in case-mix: risk-adjusted mortality did not change. Persistently very low helmet use represents the most readily actionable target for injury prevention. Beyond its clinical findings, this study illustrates the importance of explicitly accounting for data-quality differences when interpreting historical comparisons based on hospital registries.

Keywords: *Traumatic Brain Injury; Case-Mix; Information Bias; Glasgow Coma Scale; Road-Traffic Crash; Helmet; Sub-Saharan Africa; Côte d'Ivoire.*

I. INTRODUCTION

Traumatic brain injury (TBI) remains one of the leading causes of death and acquired disability among young people worldwide, and its burden continues to rise in low- and middle-income countries, where the rapid growth of the motorised two-wheeler fleet has outpaced the development of road-injury prevention and specialised care [1–4]. In West Africa, published series consistently report a stable profile: male predominance, young age, a preponderance of road-traffic crashes (RTCs) involving two-wheelers, low helmet use and delayed admission [4–7].

Most of these studies are cross-sectional and describe a single period. The temporal evolution of the TBI profile within a single centre — epidemiology, admission severity, therapeutic activity and mortality — remains little explored in the region, for want of comparable consecutive series. Comparing two successive periods makes it possible to appraise the changes observed within one centre, to explore their compatibility with changes in the road environment, the organisation of care or the patient profile, and to track public-health indicators such as helmet use.

Bouaké University Hospital is a tertiary teaching hospital and neurosurgical referral centre serving mainly central Côte d'Ivoire. It receives patients — both as first-line admissions and as transfers — from several health regions, which makes it a relevant site for observing TBI in a resource-limited setting. The centre holds data spanning two consecutive periods: a historical cohort (2016–2021) reconstructed from the departmental database, and a recent cohort (2025–2026) collected prospectively. This configuration offers a rare opportunity to compare two consecutive cohorts from a single centre while limiting the heterogeneity linked to institutional practices.

This comparison nonetheless raises a major methodological challenge that shapes the present study: the two periods are not documented with the same completeness. A retrospectively reconstructed cohort and a prospective cohort differ in completeness, exposing the analysis to differential information bias; some differences may then reflect the mode of data capture rather than a real change. Before any comparison, we therefore distinguished ascertainment-robust variables from ascertainment-sensitive variables — a variable being deemed robust when its probability of being documented was judged comparable between the two periods — and reserved the principal interpretation for the former.

The primary objective was to assess whether in-hospital mortality differed between the two periods independently of differences in admission severity (case-mix adjustment, i.e. the set of baseline characteristics influencing prognosis), applying this strategy that separates ascertainment-robust from ascertainment-sensitive variables. The secondary, descriptive objectives were to compare the epidemiological profile, initial severity, therapeutic activity and functional outcome. We hypothesised that any rise in crude mortality would be principally attributable to a more severe case-mix rather than to deteriorating care. To test this hypothesis, we compared the two cohorts according to a predefined analysis plan that prioritised variables recorded homogeneously across the two periods.

II. PATIENTS AND METHODS

➢ *Study Design and Reporting*

This was a single-centre observational study comparing two consecutive, temporally separated hospital cohorts (two-period cohort comparison), conducted in the Department of Neurosurgery of Bouaké University Hospital and reported in accordance with the STROBE guidance [8]. It is not a before–after study in the sense of an intervention, but a comparison of two observational periods. The historical cohort (2016–2021) served as the reference period; all relative estimates (odds ratios) are expressed with respect to it.

➢ *Source Population and Representativeness*

Bouaké University Hospital is a tertiary teaching and referral centre serving mainly central Côte d'Ivoire and several neighbouring health regions, both first-line and by transfer. The cohort therefore reflects the hospital TBI population of a tertiary referral centre, not all TBIs occurring in the community.

➢ *Periods, Populations and Consecutive Enrolment*

The historical cohort (2016–2021) comprised 594 patients, reconstructed from the departmental database. The recent cohort (2025–2026) comprised 772 patients, documented prospectively: enrolled at admission, with standardised capture of predefined variables throughout care. In each period, we included all consecutive patients admitted for TBI, of any age, who had undergone at least one cranial computed tomography (CT) scan and had a usable medical record. Departmental admission registers were checked to confirm exhaustive inclusion of eligible patients, without sampling. As all eligible patients were included, no a priori sample-size calculation was performed (exhaustive cohort). The flow diagram is shown in Figure 2.

The choice of the two periods corresponds to the availability of two distinct databases — a reconstructed historical one and a prospective one. No usable data were available between 2022 and 2024 owing to a discontinuity in database maintenance; this interruption precludes a continuous trend analysis and restricts the study to a comparison between two periods. As the analyses rest on individual proportions rather than annual incidence, the difference in the length of the two periods (six years vs about two years) does not affect the comparative estimates.

➢ *Variables, Definitions and Endpoints*

Severity was defined by the GCS (mild: 13–15; moderate: 9–12; severe: ≤8), in accordance with the Brain Trauma Foundation guidelines [9]. Hypotension (systolic blood pressure < 90 mmHg) was taken as a marker of secondary brain insult [9]. Mass effect was defined by sulcal effacement or ventricular/cisternal compression, herniation by midline shift, and polytrauma by the association of at least one extracranial lesion threatening life or function. The primary endpoint was all-cause in-hospital mortality. The secondary endpoint was functional outcome at a distance, assessed with the extended Glasgow Outcome Scale (GOSE), a score ≥5 (good recovery or moderate disability) defining a favourable outcome according to established use [10]; GOSE was collected at consultation, by telephone interview or from the medical record, by a departmental physician, at a median follow-up of 6 months (IQR 3–10).

In this study, case-mix denotes the set of baseline patient characteristics known to influence prognosis independently of quality of care: age, sex, neurological severity (GCS) and injury mechanism.

➢ *Comparability of Periods and a Priori Variable Classification*

To avoid interpreting a documentation gap as a clinical change, each variable was classified a priori, before any comparison, according to an explicit and reproducible criterion: does its probability of being correctly documented depend on the completeness of the record? A variable was deemed ascertainment-robust when its probability of being documented was judged comparable between the two periods, thereby limiting the risk of differential information bias. Robust variables comprised age, sex, mechanism, road-user type, helmet use, comorbidities, GCS and severity class, haemodynamic instability, mortality and functional outcome. The GCS was considered robust because it is assessed at admission according to a standardised clinical protocol in the department. Ascertainment-sensitive variables — whose recording depends on the completeness of the record — comprised acute neurological signs noted ad hoc (anisocoria, motor deficit, seizures, intubation), the detail of CT lesions, mass effect, herniation, diffuse axonal injury, polytrauma, and the surgical indication and procedures. A variable's robustness prejudged not its clinical importance but only its expected reliability in a historical comparison; classifying a variable as sensitive did not question its clinical relevance but limited its use in the principal analyses. This classification is a study-specific methodological decision, developed to interpret a comparison based on heterogeneous data; it concerned solely the risk of differential information bias, and not the intrinsic validity or clinical importance of the variables studied.

The classification of all variables and the rationale for each attribution are summarised in Table I; the overall analytical strategy that follows is schematised in Figure 1. The criteria that led to this classification are described explicitly so that the strategy can be reproduced in other studies.

Table 1 A Priori Classification of Variables by Their Robustness to Ascertainment.

Variable	Classification	Rationale	Role in analysis
Age; sex	Robust	Administrative data, systematically recorded	Primary model
Mechanism; road-user type	Robust	Recorded identically in both periods	Primary model
Helmet use	Robust	Documented in the relevant two-wheeler users	Descriptive
GCS; severity class	Robust	Assessed at admission using a standardised protocol	Primary model
Haemodynamic instability; comorbidities	Robust	History and vital signs systematically recorded	Descriptive
Mortality; functional outcome (GOSE)	Robust	Endpoints followed in both cohorts	Endpoint
Anisocoria, motor deficit, seizures, intubation	Sensitive	Signs recorded ad hoc; probable historical under-recording	Descriptive / sensitivity

Variable	Classification	Rationale	Role in analysis
Detailed CT lesions, mass effect, herniation, DAI	Sensitive	Detail dependent on completeness of the report	Descriptive
Surgical indication and procedures	Sensitive	Depends on completeness of the operative record	Descriptive

The classification reflects the expected reliability of each variable in a historical comparison, not its clinical importance. Sensitive variables (shaded) do not underpin the principal conclusions. GCS: Glasgow Coma Scale; GOSE: extended Glasgow Outcome Scale; CT: computed tomography; DAI: diffuse axonal injury.

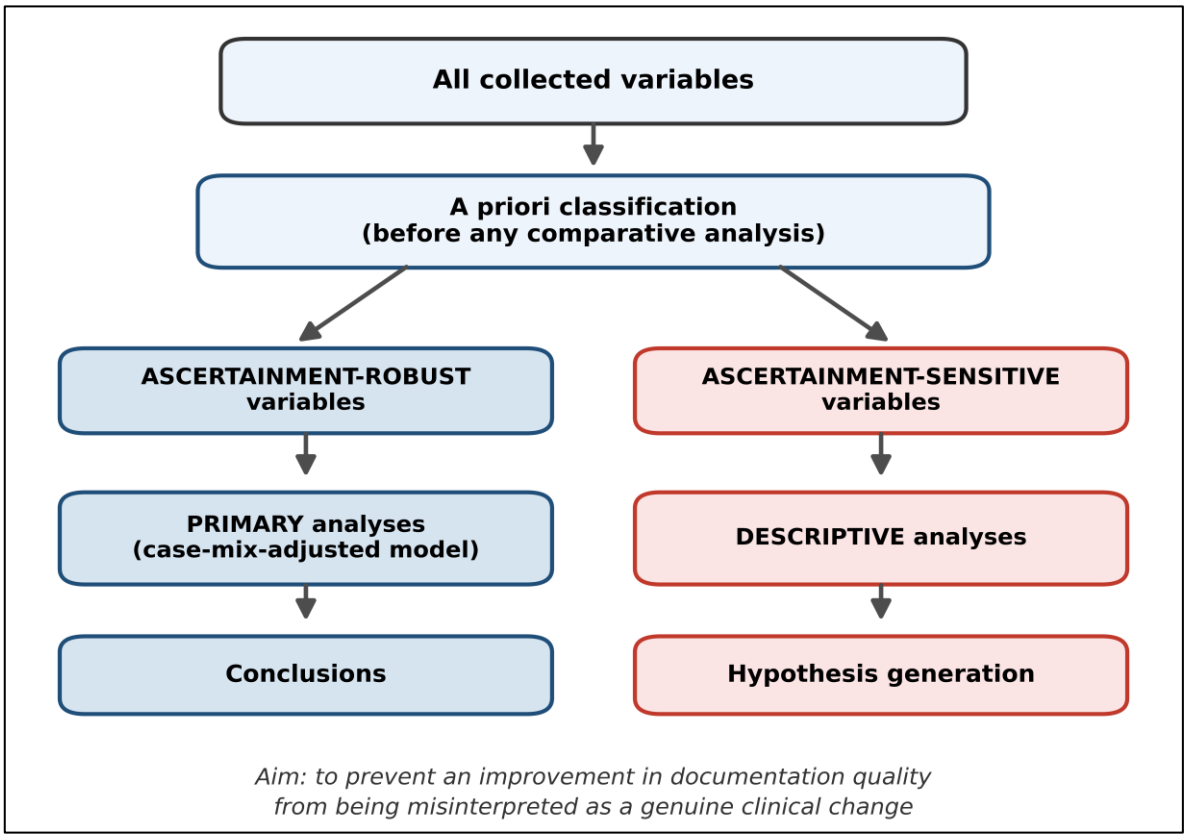

Fig 1 Methodological Framework for the a Priori Classification of Variables by Their Vulnerability to Differential Information Bias.

Variables are classified a priori, before any comparison; robust variables underpin the principal analyses and conclusions, while sensitive variables feed only descriptive analyses and hypothesis generation.

The internal consistency of this classification was assessed empirically on variables whose true frequency should not vary substantially between two nearby periods at the same centre. The data underwent a consistency check before analysis.

➢ *Handling of bias*

Three main biases were liable to affect this comparison: selection bias (inclusion only of hospitalised patients who underwent CT), differential information bias linked to distinct data-capture modes across the two periods, and residual unmeasured confounding inherent to the observational design. Specific strategies were planned to limit their effect: consecutive and exhaustive inclusion in each period, a priori classification of variables by their sensitivity to ascertainment, restriction of interpretation to variables recorded homogeneously, and adjustment of the primary endpoint for admission case-mix. Residual confounding cannot, however, be entirely excluded despite multivariable adjustment.

➢ *Statistical analysis*

Analyses followed a predefined order: description of the two cohorts; univariate comparison; stratified analysis by severity (GCS); crude logistic regression; adjusted regression; sensitivity analysis. Categorical variables are expressed as counts and percentages, continuous variables as median [interquartile range]. The Mann–Whitney test was used for continuous variables (non-Gaussian distributions) and the chi-square or Fisher exact test (expected counts < 5) for categorical variables. Bivariate comparisons were regarded as exploratory; no correction for multiple comparisons was applied and p-values are interpreted cautiously, with emphasis on estimates and their 95% confidence intervals (95% CI). All tests were two-sided and a threshold of $p < 0.05$ was used.

For the primary endpoint, the effect of the inclusion period on mortality was estimated by logistic regression,

crude then adjusted. As mortality was assessed only during hospitalisation, without variable follow-up time, logistic regression was the appropriate method (a Cox or Poisson survival model was not relevant in the absence of usable follow-up time). Covariates were chosen a priori on clinical and methodological grounds rather than through an automatic selection procedure, irrespective of their univariate significance, and restricted to ascertainment-robust variables; the primary model therefore adjusted for age, sex, GCS and mechanism (RTC vs other), excluding any ascertainment-sensitive variable. A sensitivity model added anisocoria; this choice rested on its strong clinical prognostic value despite its ascertainment-sensitive nature, and aimed to verify the stability of the estimates. The GCS was entered as a continuous variable after checking for the absence of a significant departure from linearity on the logit (non-significant quadratic term, p=0.13). The absence of substantial collinearity was confirmed (all variance inflation factors < 1.25). A period × GCS interaction, specified a priori, was tested and was not significant (p=0.22); it was not retained, so the final model contained no interaction. No major violation of the model assumptions was found. Discrimination was assessed by the area under the ROC curve (AUC) and calibration by the Hosmer–Lemeshow test, interpreted cautiously given its known limitations. The number of events (48 deaths) allowed four to five covariates (about 10 events per variable). Missing data were near-nil for admission variables (helmet use excepted); functional outcome was missing for 120 patients (lost to follow-up). No imputation of missing data was performed; analyses were conducted on complete cases (complete-case analysis). All methodological choices (variable classification, adjustment strategy, sensitivity analyses) were defined before the analytical database was opened, to limit result-driven decisions. Analyses were performed with Python version 3.12 (pandas, SciPy 1.17, statsmodels 0.14); scripts are available from the corresponding author on reasonable request.

III. RESULTS

➢ *Population And Flow*

In total, 1,366 patients were included in the analysis: 594 during 2016–2021 (historical cohort) and 772 during 2025–2026 (recent cohort) (Figure 2). Functional outcome was documented in 1,246 patients; 120 patients had no documented functional outcome, comprising 48 deaths and 72 surviving patients lost to follow-up. These 72 survivors lost to follow-up represented 5.5% of survivors, with no significant difference between periods (39/582 [6.7%] vs 33/736 [4.5%]; p=0.08). The median follow-up for functional-outcome assessment was 6 months (IQR 3–10); among evaluable patients, 86.4% were assessed at ≥3 months, 57.8% at ≥6 months and 23.3% at ≥12 months. The baseline characteristics of those lost to follow-up (age, sex, GCS, severity) did not differ from those of the patients followed (p ≥ 0.10), and this loss to follow-up concerned only the functional-outcome analysis, without affecting the in-hospital mortality analysis. No systematic pattern of loss to follow-up was identified.

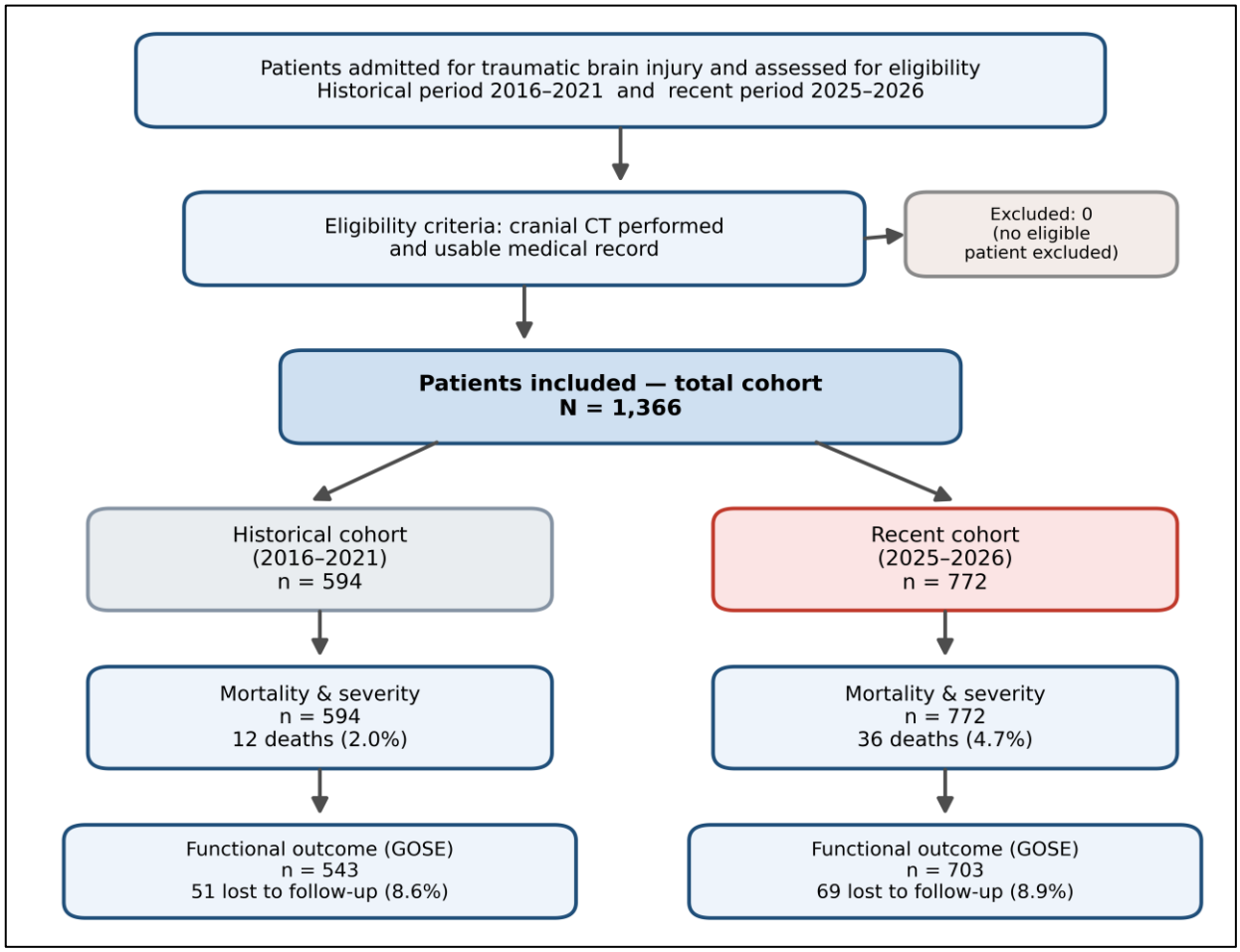

Fig 2 Study flow diagram (STROBE).

Consecutive and exhaustive inclusion in each period; no eligible patient was excluded after verification of the inclusion criteria. Numbers analysed for mortality/severity and for functional outcome.

➢ *Comparative Epidemiology*

The two cohorts had broadly comparable demographic characteristics: median age remained 30 years (p=0.433), while the proportion of men fell modestly (89.2% vs 83.8%; p=0.004). The distribution of injury mechanisms shifted toward a greater predominance of road-traffic crashes (Figure 3): RTCs rose from 75.3% to 89.4% and the share of motorised two-wheeler users from 68.5% to 77.1%, with the emergence of three-wheeler crashes (0.3% to 2.6%; p<0.001); falls (15.5% to 6.1%) and assaults (9.3% to 3.9%) declined. Helmet use among documented two-wheeler users remained very low and did not differ between periods (5.6% [95% CI 3.8–8.2] vs 5.2% [95% CI 3.7–7.2]). The proportion of patients referred from another facility fell (57.6% vs 50.4%; p=0.008), while the median admission delay remained two days (Table II).

Table 2 Comparative Epidemiological Characteristics (Ascertainment-Robust Variables).

Variable	Historical (n=594)	Recent (n=772)	p
Median age (years) [IQR]	30 [21–41]	30 [20–44]	0.433
Male sex	530 (89.2%)	647 (83.8%)	0.004
RTC (all users)	447 (75.3%)	690 (89.4%)	<0.001
Motorised two-wheeler user	407 (68.5%)	595 (77.1%)	<0.001
Three-wheeler user	2 (0.3%)	20 (2.6%)	<0.001
Fall	92 (15.5%)	47 (6.1%)	<0.001
Assault	55 (9.3%)	30 (3.9%)	<0.001
Helmet use (documented two-wheeler users)	24/428 (5.6%)	33/640 (5.2%)	0.76
Initial loss of consciousness	379 (63.8%)	397 (51.4%)	<0.001
Referred patient	342 (57.6%)	389 (50.4%)	0.008
Admission delay > 48 h	225 (37.9%)	269 (34.8%)	0.24
Hypertension	86 (14.5%)	126 (16.3%)	0.36
Chronic alcohol use	108 (18.2%)	156 (20.2%)	0.35

Tests*: c*hi-square or Fisher (categorical), Mann–Whitney (age). Denominator = total size of each cohort, except helmet use, reported among all two-wheeler users with recorded helmet status — riders and pillion passengers (denominators 428 and 640) — a count higher than the number of motorised two-wheeler riders reported above. IQR: interquartile range; RTC: road-traffic crash.

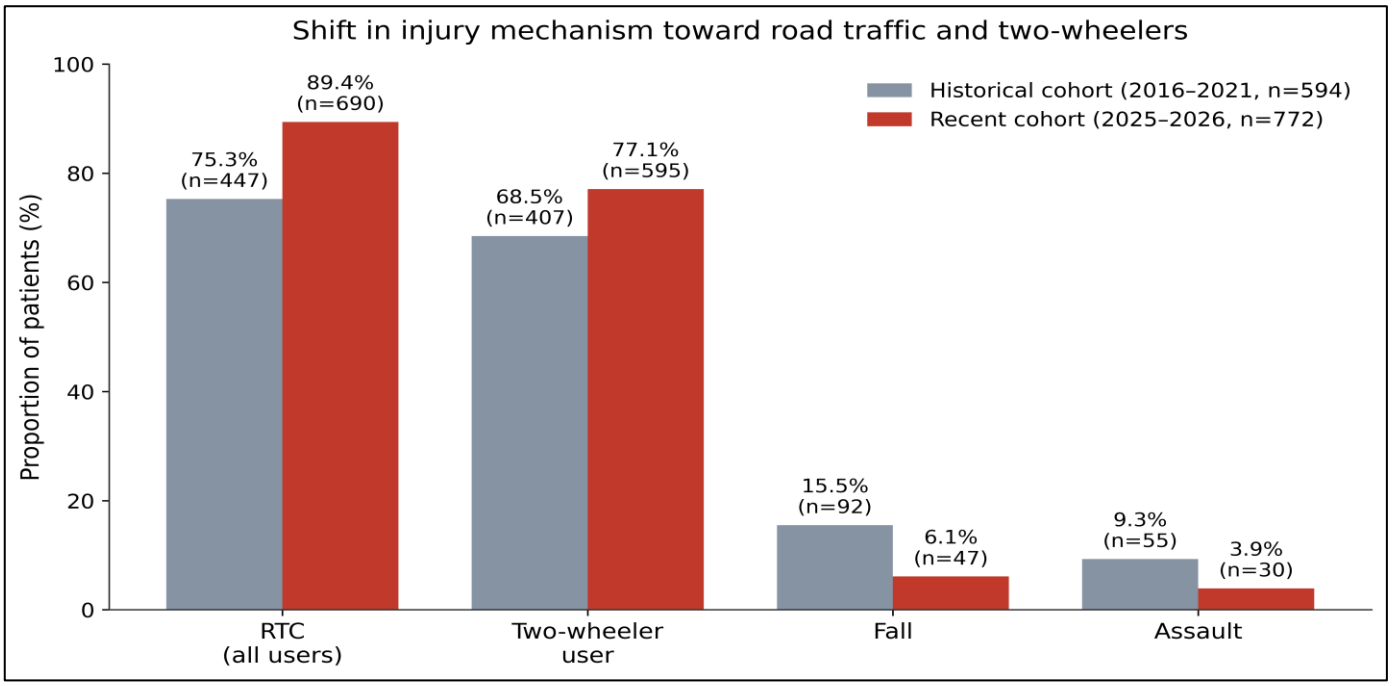

Fig 3 Shift of the Injury Mechanism Toward Road Traffic and Two-Wheelers Between the two Periods (Counts and Percentages).

➢ *Admission Severity*

Neurological severity at admission was more marked in the recent period (Figure 4, which illustrates the shift of the distribution toward moderate and severe forms): the median GCS fell from 14 [13–15] to 13 [11–14] ($p<0.001$), the proportion of severe TBI from 1.3% to 7.9% and that of moderate TBI from 23.4% to 35.9%, at the expense of mild forms (75.3% to 56.2%; $p<0.001$). Haemodynamic instability remained stable (5.6% vs 6.7%; $p=0.371$). Recorded acute neurological signs (anisocoria, motor deficit, seizures, intubation) rose sharply; being ascertainment-sensitive, these comparisons are reported descriptively and should not be interpreted as a temporal clinical change (Table 3).

Table 3 Admission Severity and Clinical Presentation.

Admission parameter	Historical (n=594)	Recent (n=772)	p
Median GCS [IQR]	**14 [13–15]**	**13 [11–14]**	**<0.001**
Mild TBI (GCS 13–15)	447 (75.3%)	434 (56.2%)	<0.001
Moderate TBI (GCS 9–12)	139 (23.4%)	277 (35.9%)	<0.001
Severe TBI (GCS ≤8)	8 (1.3%)	61 (7.9%)	<0.001
Haemodynamic instability	33 (5.6%)	52 (6.7%)	0.371
Anisocoria †	1 (0.2%)	81 (10.5%)	<0.001
Motor deficit †	2 (0.3%)	128 (16.6%)	<0.001
Seizures †	5 (0.8%)	93 (12.0%)	<0.001
Intubation at admission †	20 (3.4%)	111 (14.4%)	<0.001

Tests: chi-square/Fisher; Mann–Whitney (GCS). † Ascertainment-sensitive variables, not entered in the primary model: comparisons reported descriptively only (see Methods). GCS: Glasgow Coma Scale.

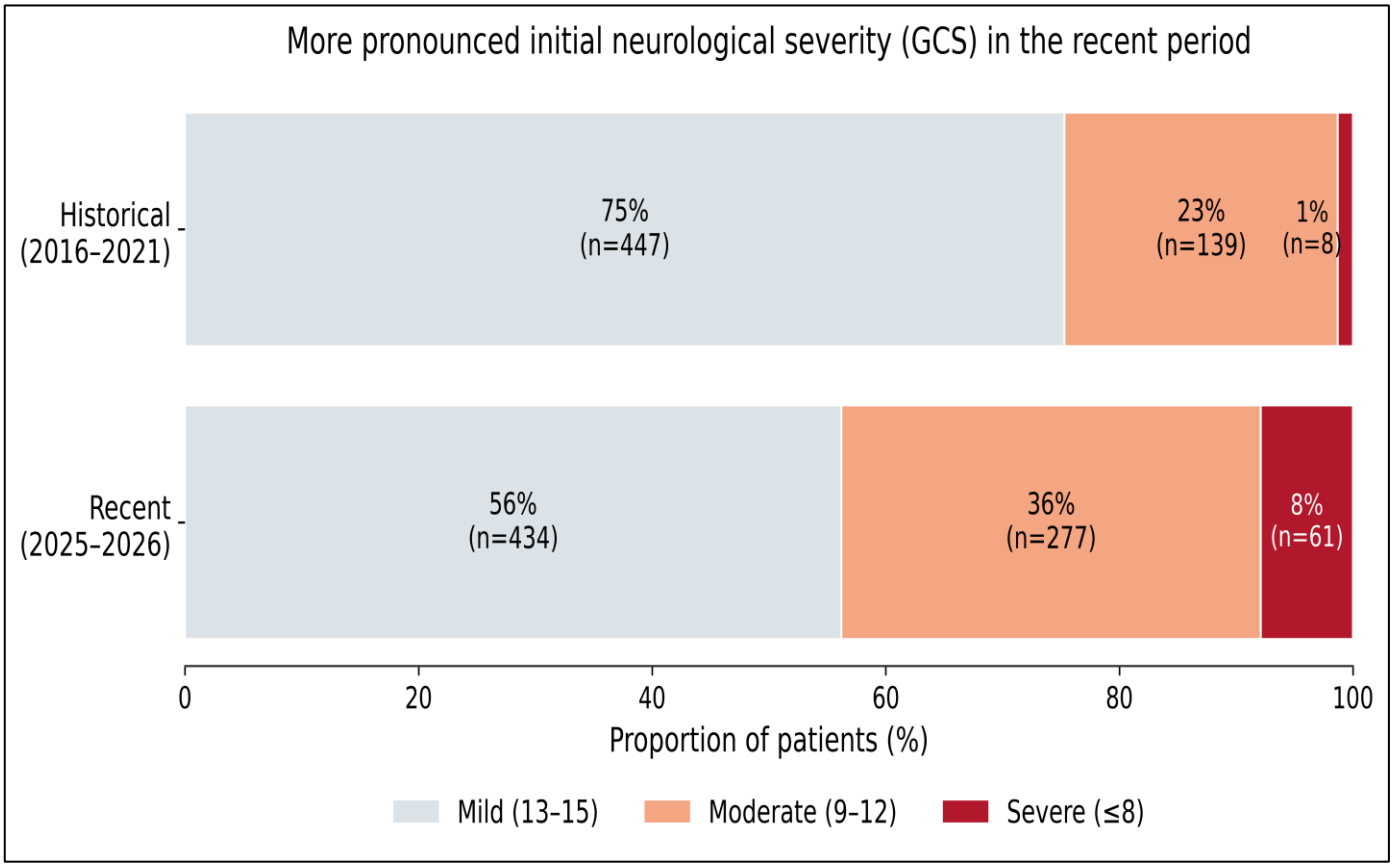

Fig 4 Initial neurological severity (GCS classification) by period: shift toward moderate and severe forms in the recent period (counts and percentages).

➢ *CT Profile and Surgical Activity (Secondary Descriptive Analyses)*

These data derive from secondary descriptive analyses and from variables classified a priori as ascertainment-sensitive; the comparisons are reported descriptively and are not interpreted as a temporal change. The proportion of scans without a documented focal lesion fell from 43.1% to 17.2%, and most lesion categories increased — except intraparenchymal contusion/haematoma, which remained stable (43.8% vs 43.5%). The documented surgical indication rose from 9.9% to 72.9% (Table IV).

Table 4 CT Profile and Surgical Activity (Secondary Descriptive Analyses).

Lesion / procedure (ascertainment-sensitive)	Historical (n=594)	Recent (n=772)	p
Contusion / intraparenchymal haematoma	260 (43.8%)	336 (43.5%)	0.927
Extradural haematoma	25 (4.2%)	100 (13.0%)	<0.001
Acute subdural haematoma	39 (6.6%)	110 (14.2%)	<0.001
Subarachnoid haemorrhage	25 (4.2%)	116 (15.0%)	<0.001
Mass effect	24 (4.0%)	230 (29.8%)	<0.001
Depressed skull fracture	16 (2.7%)	82 (10.6%)	<0.001
Diffuse axonal injury	3 (0.5%)	72 (9.3%)	<0.001
No documented focal lesion	256 (43.1%)	133 (17.2%)	<0.001
Surgical indication	59 (9.9%)	563 (72.9%)	<0.001
Haematoma evacuation / drainage	47 (7.9%)	139 (18.0%)	<0.001
Decompressive craniectomy	0 (0.0%)	63 (8.2%)	<0.001

All these variables are ascertainment-sensitive; descriptive comparisons only. Test: chi-square/Fisher. Denominator = total size of each cohort.

- *Mortality and Functional Outcome*

Crude in-hospital mortality was higher in the recent period: 4.7% (95% CI 3.4–6.4) vs 2.0% (95% CI 1.2–3.5), an absolute difference of 2.6 percentage points (95% CI 0.8–4.5; p=0.009). Favourable outcome (GOSE ≥5) among evaluable survivors was slightly less frequent (94.5% [95% CI 92.5–95.9] vs 97.1% [95% CI 95.3–98.2]; p=0.027), in parallel with the greater admission severity. Stratum-specific mortality (Figure 5B) was comparable between periods for mild (1.1% vs 1.2%) and moderate (4.3% vs 5.4%) TBI; a difference was observed mainly in the severe stratum (12.5% vs 26.2%), though the historical count there was very small (n=8) and the estimate imprecise (Table V).

Table 5 In-Hospital Mortality and Functional Outcome, Overall and by Severity Stratum.

Outcome	Historical (n=594)	Recent (n=772)	p
In-hospital mortality (all causes)	**12 (2.0%)**	**36 (4.7%)**	**0.009**
Favourable outcome (GOSE ≥5, evaluable)	527/543 (97.1%)	664/703 (94.5%)	0.027
Mortality — mild TBI	5/447 (1.1%)	5/434 (1.2%)	—
Mortality — moderate TBI	6/139 (4.3%)	15/277 (5.4%)	—
Mortality — severe TBI	1/8 (12.5%)	16/61 (26.2%)	—

Test: chi-square/Fisher. Stratum-specific comparisons are not tested (small counts). GOSE: extended Glasgow Outcome Scale.

- *Case-Mix-Adjusted Mortality*

The effect of the inclusion period on mortality, marked in crude analysis (OR 2.37; 95% CI 1.22–4.60; p=0.011), was no longer significant after adjustment for admission case-mix: adjusted OR 1.23 (95% CI 0.60–2.52; p=0.57) (Figure 5A, Table VI). The dominant determinant was the GCS (OR 0.63 per point; 95% CI 0.56–0.72; p<0.001). The model showed good discrimination (AUC 0.78); the Hosmer–Lemeshow test revealed no major calibration defect (p=0.47), although this test has known limitations, notably low power with small samples. Conclusions were unchanged in the sensitivity analysis adding anisocoria (OR 1.20; 95% CI 0.58–2.50). These analyses suggest that the rise in crude mortality in the recent period is principally attributable to the observed differences in case-mix; at comparable severity, the data did not reveal a difference in mortality.

Table 6 Effect of period on in-hospital mortality (logistic regression; n=1,366; 48 deaths).

In-hospital mortality model (n=1,366; 48 deaths)	OR	95% CI	p
Recent period — crude effect	2.37	1.22–4.60	0.011
Recent period — primary model*	**1.23**	**0.60–2.52**	**0.57**
GCS (per point, primary model)	**0.63**	**0.56–0.72**	**<0.001**
Age (per year, primary model)	0.99	0.98–1.01	0.52
Recent period — sensitivity model †	1.20	0.58–2.50	0.62

* Primary model adjusted for age, sex, GCS and RTC mechanism (ascertainment-robust variables; AUC 0.78; Hosmer–Lemeshow p=0.47). † Sensitivity model = primary model + anisocoria. Reference period: historical cohort. OR: odds ratio; CI: confidence interval.

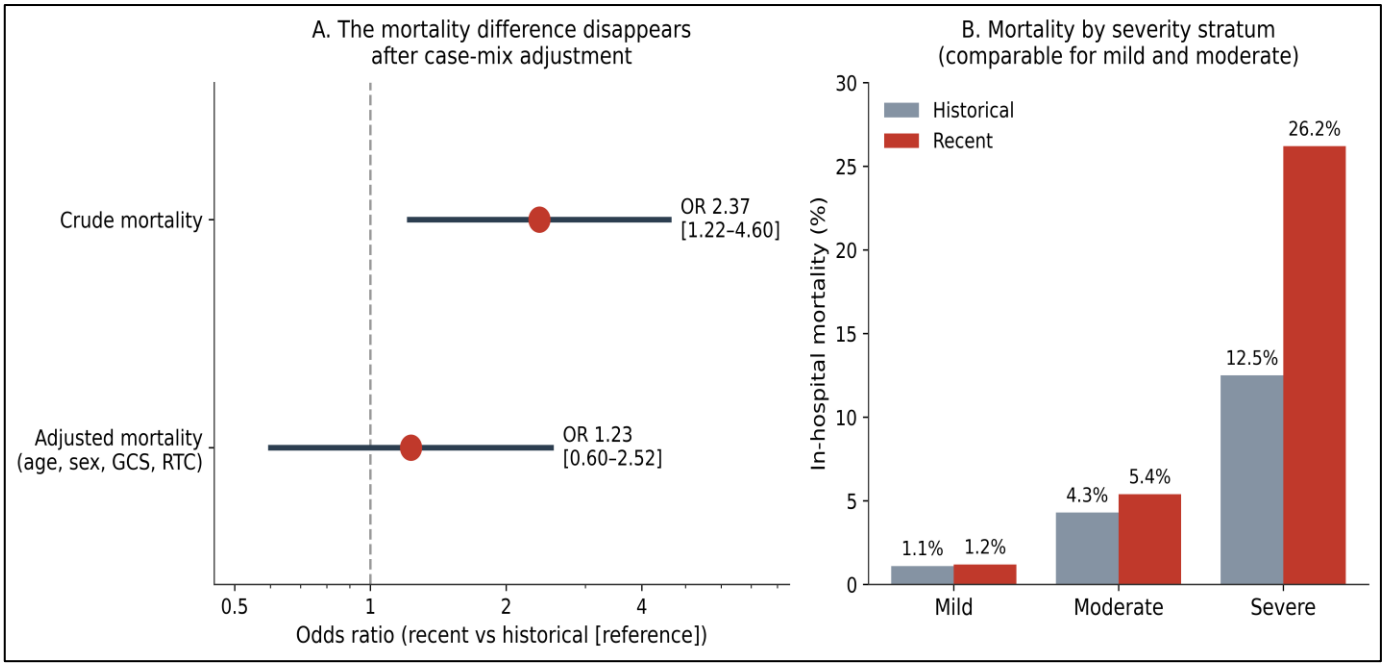

Fig 5 (A) Effect of period on mortality, crude then case-mix-adjusted: the crude association is no longer significant after adjustment. (B) Mortality by severity stratum, comparable for mild and moderate TBI.

IV. DISCUSSION

This comparative analysis of two consecutive cohorts from a single Ivorian centre yields three main findings. First, no independent difference in in-hospital mortality was found between the two periods after adjustment for admission case-mix. Second, the recent cohort had greater initial neurological severity and a greater predominance of road-traffic crashes. Third, several differences observed for ascertainment-sensitive variables appeared more compatible with improved documentation than with a real change in the patients' clinical characteristics. We discuss these points in turn, then their methodological and public-health implications.

➢ *Initial Severity and Case-Mix-Adjusted Mortality*

The recent cohort included more severe patients (on the basis of the GCS, a homogeneously recorded variable) and had higher crude mortality. The stratified analysis and the adjusted model converge in attributing this excess mortality to case-mix: stratum-specific mortality was comparable for mild and moderate TBI, and, after adjustment for admission case-mix, no statistically significant difference in in-hospital mortality was found between the two periods (OR 1.23; p=0.57), with the GCS remaining the dominant determinant, a result stable in sensitivity analysis. These results are compatible with stable severity-adjusted in-hospital mortality between the two periods; they do not, however, allow a direct assessment of quality of care. This finding underscores the importance of distinguishing differences linked to the patients' initial profile from those genuinely attributable to a change in quality of care, and it is a reminder that comparing crude mortality across periods is insufficient without adjustment for initial severity. The GCS remains one of the principal prognostic determinants of TBI and an unavoidable adjustment factor in temporal comparisons; its central place in our model matches its established prognostic value in large international cohorts and the Brain Trauma Foundation guidelines [9,16]. The increased share of severe patients may stem from several non-exclusive factors: more violent motorisation-related crashes, changes in referral pathways concentrating heavy cases at the referral centre, better pre-hospital survival bringing severe patients to hospital, or better identification of severe forms; our data cannot disentangle them. As this is an observational comparison between two periods, these associations do not establish a causal link between the observed changes and the evolution of the health or road environment: a period effect may also reflect changes in the care system, in diagnostic practices (greater CT availability) or in referral patterns.

➢ *Epidemiological Evolution*

The rise in RTCs (75% to 89%) and in the share of two-wheeler users, together with the appearance of a non-negligible fraction of three-wheeler crashes, are consistent with the rapid motorisation dynamic described in West Africa [3,4,11]. Recorded homogeneously across periods, these variables rest on comparable ascertainment and can therefore be interpreted with greater confidence. The relative decline of falls and assaults is compatible with an increasing share of road-traffic crashes rather than an absolute decrease in these mechanisms. The emergence of three-wheelers, still little described in the regional literature, deserves particular attention, as these vehicles often carry several unprotected passengers; this observation will need confirmation in dedicated studies. The slight rise in the proportion of women (from 10.8% to 16.2%) might reflect increased exposure of women to two- and three-wheeler transport; this hypothesis requires confirmation.

The profile we describe — young, male-predominant, with a preponderance of road-traffic crashes — matches recent West- and East-African series. The Nigerian systematic review pooling 45,763 patients reports an RTC share of about 69% and a mean age near

32 years [12], and a cross-sectional Lagos series reports comparable proportions [13]. The heterogeneity of regional trauma profiles, already noted in the Chadian N'Djamena series [18], calls for caution in these comparisons; the clear predominance of two-wheelers in Bouaké nonetheless brings our series closer to high-motorisation settings. Reviews devoted to TBI in low- and middle-income countries further point to hospital mortality generally higher than ours [15], and some regional multicentre series report early mortality after road crashes of the order of 10–15% [14]; this gap probably reflects patient selection and the hospital nature of our cohort.

- *Methodological Lessons: A Differential Information Bias*

The main methodological lesson lies in the magnitude of certain contrasts. That an elementary clinical sign such as anisocoria should be recorded sixty times more often in the recent period, or that the surgical indication should rise from 10% to 73% at the same centre within a few years, is hard to reconcile with a real clinical change. Conversely, the stability of prevalent comorbidities, of helmet use, of haemodynamic instability — and, among lesions, of contusion alone (the dominant lesion, always recorded) — strongly suggests under-recording in the historical period. This asymmetry corresponds to differential information bias (differential misclassification), particularly liable to affect historical comparisons pitting retrospective data against prospectively collected data. Our approach does not consist in excluding these variables from the analysis, but in adapting the confidence placed in their interpretation according to their vulnerability to this bias. The explicit, a priori distinction between ascertainment-robust and ascertainment-sensitive variables is, in this respect, a methodological contribution of this work, transferable to the many temporal comparisons that, in sub-Saharan Africa, will have to contend with data of unequal completeness. This classification rests, however, on a line of reasoning developed for this study; it is not a universal framework and will need confirmation in other temporal comparisons using heterogeneous databases.

- *Public-Health Implications*

The most directly actionable finding is the stability of helmet use at a very low level (about 5%) among two-wheeler users, across two periods and more than a thousand documented users. Measured on homogeneous data, this figure is a reliable estimate, and its lack of improvement — while the share of two-wheelers was rising — underscores the failure, to date, of primary prevention. Generalising helmet use remains the most accessible intervention to reduce the incidence and severity of two-wheeler-related TBI [4]. Beyond the helmet, maintaining a median admission delay of two days, organising inter-hospital transfers, pre-hospital care and curbing excessive speed are complementary levers. The high share of referred patients and the observed admission delay argue for strengthening transfer pathways and structuring a regional trauma network, so as to shorten the time to neurosurgical care. Developing pre-hospital care (oxygenation, haemodynamic control, immobilisation) could limit secondary brain insults before admission. Finally, the growth of two- and three-wheelers justifies targeted road-safety policies (mandatory helmet use, speed control, regulation of passenger transport).

- *Applicability*

This ascertainment-robustness-based analysis strategy (robustness-based comparison strategy) could be used in other historical comparisons resting on hospital registries, particularly in settings where documentation quality has improved gradually over time. Its transposition would require, in each setting, an explicit a priori classification of variables and an empirical check of that classification. This strategy does not replace the classical methods of bias control but complements them when data-capture quality differs between the periods compared.

- *Strengths*

Among the main strengths of this study are the comparison of two consecutive cohorts from a single centre — a rare configuration in the region, limiting practice heterogeneity — substantial numbers (1,366 patients), completeness of the key admission variables, case-mix adjustment with sensitivity analysis, and an explicit, a priori strategy for separating contrasts by their sensitivity to ascertainment, empirically assessed. The a priori definition of the analytical strategies is also a strength, limiting result-driven analyses. To our knowledge, few case-mix-adjusted historical comparisons have been reported from neurosurgical centres in sub-Saharan Africa.

- *Limitations*

Several limitations must be considered, which can be grouped by type of bias. Selection bias: only hospitalised patients who underwent CT were included; although CT is near-systematic at the centre, this criterion may have excluded patients who died before imaging or mild TBIs not scanned. The results therefore concern hospitalised patients and do not allow estimation of the incidence of TBI in the general population; in-hospital mortality further underestimates true mortality, as deaths after discharge are not captured. Information bias: the asymmetry of ascertainment between a reconstructed historical cohort and a recent prospective one precludes any conclusion about the real evolution of CT lesions and surgical practices, reported descriptively. Residual confounding: several prognostic factors were unavailable (precise pre-hospital delay, severity of extracranial lesions, desaturation, acute alcohol use, crash speed, seat-belt use), and residual confounding cannot be excluded, inherent to the observational design. Moreover, the first period (2016–2021) includes the COVID-19 pandemic years, liable to have altered patient flows and the organisation of care; this effect was not assessed. The classification of variables by robustness rests partly on methodological judgement and will need confirmation in other settings and other databases. The proposed classification has not yet undergone external validation in other hospital registries. The model was not internally validated by bootstrap or cross-validation; its performance will need confirmation in

independent datasets. The reproducibility of this analysis strategy will also need to be assessed in independent multicentre databases. Finally, the small number of deaths (48, including 12 in the historical period) limits the precision of the model, particularly in the historical severe stratum (n=8); the absence of a difference after adjustment should therefore be understood as the absence of a strong signal rather than proof of equivalence, and the single-centre nature restricts external validity. The relatively limited number of events warrants cautious interpretation of the adjusted estimates, despite the consistency of the sensitivity analyses. Despite these limitations, the main results rest on variables recorded homogeneously across the two periods, which strengthens their robustness.

➢ *Generalisability and Perspectives*

These results are potentially transferable to West African referral centres with a comparable organisation (high two-wheeler motorisation, limited resources, transfer pathways), but their transposition to rural or first-line centres lacking CT and neurosurgical facilities is more uncertain. Setting up a standardised prospective registry, with a common data dictionary and functional follow-up at 3, 6 and 12 months and compliant with the RECORD recommendations for routinely collected data [17], would turn these two heterogeneous cohorts into a homogeneous time series allowing genuine trend analyses and evaluation of prevention interventions. Multicentre studies will help confirm the reproducibility of this methodological approach in other sub-Saharan African settings; external validation of the variable-classification strategy would be an important step before wider dissemination. A multicentre extension (Bouaké–Abidjan) would strengthen external validity.

➢ *Key Messages*

- The recent cohort was more severe and had higher crude mortality (4.7% vs 2.0%), yet case-mix-adjusted mortality did not change (OR 1.23; p=0.57): comparing crude mortality without adjusting for initial severity can lead to a mistaken interpretation.
- Any single-centre temporal comparison must distinguish real changes from ascertainment artefacts: the a priori classification of variables by ascertainment robustness offers a pragmatic framework to limit differential information bias.
- Helmet use remained very low and unchanged (≈5%): its generalisation remains the most accessible and immediately actionable prevention priority.
- The share of road-traffic crashes and motorised two-wheelers rose between the two periods (RTC 75%→89%), with the emergence of three-wheeler crashes.

V. CONCLUSION

Across two consecutive periods at a single Ivorian referral centre, crude in-hospital mortality from TBI rose, but the data did not reveal a statistically significant difference after adjustment for admission case-mix: this rise was principally attributable to a more severe admission profile (as assessed by the GCS) and to a greater predominance of motorisation-related injuries. In practical terms, generalising helmet use — which remained very low — is a public-health priority, alongside the establishment of a standardised prospective registry. Beyond these clinical results, this study underscores that a historical comparison can be interpreted correctly only after simultaneously accounting for case-mix and data-capture quality, and to that end proposes a pragmatic methodological framework applicable to historical comparisons based on hospital data of heterogeneous documentation quality, subject to external validation.

DECLARATIONS

➢ *Ethics Approval and Consent.*

This study was approved by the Ethics Committee of Bouaké University Hospital (No. CEI/CHU-BKE/125/2026) and conducted in accordance with the Declaration of Helsinki. Data were anonymised before analysis; given the partly retrospective nature of the study, a waiver of individual informed consent was granted, with anonymity and confidentiality preserved.

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This study received no specific funding.

➢ *Conflicts of Interest.*

The authors declare no conflict of interest related to this work.

➢ *Data and Code Availability.*

The anonymised data, the data dictionary and the analysis scripts may be made available by the corresponding author on reasonable request, subject to institutional authorisations.

AUTHOR CONTRIBUTIONS (CREDIT).

Conceptualisation: TL; Methodology: TL, KKJB, YKS; Investigation and data curation: DKYS, FYB; Formal analysis: TL, KKJB; Writing — original draft: TL; Writing — review and editing: DKYS, FYB, TL; Supervision: AH. All authors approved the final version.

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