

No Independent Association Detected between Lesion Morphology and Neurological Outcome: AOSpine and ASIA Assess Distinct Dimensions in a West African Cohort of 366 Traumatic Spinal Injuries

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Abstract

Background and Objective: The AOSpine classification describes the morphology of traumatic spinal injuries, whereas the ASIA grade assesses neurological impairment. The prognostic value of lesion morphology itself remains debated and has rarely been studied in African cohorts. The objective was to determine whether the AOSpine classification retains prognostic value after adjustment for ASIA grade. **Methods:** Single-centre cohort of 366 traumatic spinal injuries managed at Bouaké Teaching Hospital, Côte d'Ivoire, reported according to STROBE. Injuries were classified using the AOSpine thoracolumbar and subaxial cervical systems and grouped into types A, B and C. Bivariate comparisons, adjusted logistic regression and analysis stratified by spinal segment were performed. **Results:** Injuries were type A in 34.7%, type B in 21.9% and type C in 43.4%. AOSpine type was associated with dislocation, disco-ligamentous injury and cord compression ($p < 0.001$). The distribution of ASIA grades did not differ across types ($p = 0.221$), but the proportion of complete injuries rose from 31.5% to 47.2% from type A to type C (adjusted trend $p = 0.015$). AOSpine type was associated neither with mortality (18.1%, 15.0%, 18.2%) nor with recovery (52.3%, 41.0%, 43.4%). In multivariable analysis, only ASIA grade remained associated with outcome (mortality: adjusted odds ratio 11.34; recovery: 0.49). Adding AOSpine type to ASIA-based models did not improve corrected discrimination ($\Delta\text{AUC} +0.011$ for mortality, -0.011 for recovery). **Conclusion:** The AOSpine classification accurately describes the mechanical severity of the injury, but nei-

ther an independent prognostic association nor a substantial incremental predictive gain beyond ASIA grade was detected, and the confidence intervals remain compatible with modest effects. The two classifications assess distinct dimensions and should be documented jointly.

Keywords

Classification, Côte d'Ivoire, Prognosis, Spinal Cord Injuries, Spinal Injuries

1. Introduction

Traumatic spinal injuries (TSI) are a major cause of lasting disability and excess mortality, particularly in low- and middle-income countries, where road traffic collisions predominate and where access to specialised neurosurgical care remains limited [1]-[5]. In a patient with a traumatic spinal injury, the surgeon must answer two questions at once: does the spine need to be stabilised, and what is the potential for neurological recovery? Both decisions govern the therapeutic strategy, the information given to the family and the organisation of rehabilitation. They rest on two distinct assessments: the morphological characterisation of the osseo-disco-ligamentous injury on the one hand, and the assessment of the severity of neurological impairment on the other.

The AOSpine classification standardises the morphological description of traumatic spinal injuries. It distinguishes three main types according to the injury mechanism: compression of the vertebral body (type A), tension band injury (type B) and translation or displacement reflecting major instability (type C), both at the thoracolumbar [6] and at the subaxial cervical level [7]. Derived severity scores have been proposed to guide the surgical algorithm [8]-[10]. In parallel, neurological severity is graded using the American Spinal Injury Association Impairment Scale (ASIA), within the framework of the International Standards for Neurological Classification of Spinal Cord Injury (ISNCSCI) [11] [12]; the ASIA grade on admission is the main prognostic factor for neurological and vital outcomes, and the value of early decompression is established [13]-[15].

These two systems explore different dimensions of the injury: AOSpine describes the mechanical involvement of the spinal column, whereas ASIA quantifies the functional involvement of the spinal cord. Their correlation is neither constant nor mandatory, and the prognostic value of the AOSpine classification in its own right—beyond its role in decision-making—remains debated [16]. This question has rarely been examined in African cohorts: few series reach a sufficient size, and few combine AOSpine, ASIA and multivariable analyses. We hypothesised that AOSpine type would be strongly associated with the mechanical characteristics of the injury, but that it would add no independent neurological prognostic value once ASIA grade was taken into account. The primary objective was to compare, within a single cohort, morphological information and neurological information in patients managed at Bouaké Teaching Hospital.

2. Patients and Methods

2.1. Study Design, Setting and Population

This was a single-centre cohort study conducted in the Department of Neurosurgery of Bouaké Teaching Hospital, Côte d'Ivoire, combining a retrospective phase (2017-2021) and a prospective phase conducted from January 2025 to June 2026, and reported according to the STROBE recommendations [17]. Patients admitted for a traumatic spinal injury confirmed clinically and on imaging were included. Non-traumatic conditions, duplicate records and inconclusive cases identified during the quality audit of the database were excluded. In total, 383 records were assessed for eligibility and 17 were excluded: 9 non-traumatic spinal or spinal cord conditions, 5 duplicate records and 3 records that remained inconclusive or unusable after source verification. The main analysed population therefore comprised 366 patients.

Administrative location fields were harmonised before analysis. The categories “Bouaké Teaching Hospital” and “Bouaké” were merged. Records carrying another administrative location were cross-checked, where possible, against admission registers and operative reports in order to distinguish the patient's place of origin from the centre where care was actually delivered. These administrative variables were used neither as clinical inclusion criteria nor as prognostic variables. All included patients were managed and followed up within the Department of Neurosurgery of Bouaké Teaching Hospital, where every surgical procedure, when indicated, was performed: the study is single-centre. Specific analyses were performed on the relevant subpopulations: 366 patients for the descriptive analyses and the mortality model, 345 operated patients for operative modalities (fusion, surgical approach) and 262 survivors with an initial deficit for the analysis of neurological recovery. The documented follow-up duration had a median of 45 days (14 - 180), with a range of 1 to 365 days.

Data collection combined a retrospective and a prospective component. The exact distribution of inclusions by period could not be fully reconstructed from the date variable, which was missing for some records. No definitive conclusion regarding the absence of inclusions between 2022 and 2024 was therefore drawn without further verification of the source registers.

2.2. Variables, Classification and Missing Data

Injuries were classified using the AOSpine thoracolumbar [6] and subaxial cervical [7] systems, on the basis of imaging (computed tomography $\pm$ magnetic resonance imaging) and the operative report, by the neurosurgical team caring for the patient. For analysis, the subtypes (A0 - A4, B1 - B3, C) were grouped into three main morphological types: A (compression), B (tension band) and C (translation). No formal assessment of inter-observer agreement was performed as part of this work. The eleven sacral injuries were classified using the thoracolumbar grid and analysed with the thoracolumbar stratum, although a dedicated AOSpine sacral system has been available since 2020 [18]; this harmonisation choice is addressed as a methodological limitation. The neurological (N0 - N4) and clinical

(M1 - M2) modifiers of the classification [19] were not recorded systematically and were not analysed.

Neurological deficit was graded using the ASIA/ISNCSCI scale [11] [12]. Spinal instability, dislocation, spinal cord compression and contusion, and disco-ligamentous injury were documented from imaging and the operative report. The variable “dislocation” denoted any vertebral malalignment demonstrated on imaging—facet subluxation, partial malalignment, vertebral slippage or complete translation—and should not be equated with AOSpine type C, which implies true translation. The dislocation variable and the AOSpine type were abstracted independently: dislocation was coded from the wording of the imaging report, whereas the AOSpine type was assigned by the neurosurgical team after full review of the imaging and operative findings. The two codings were deliberately not harmonised post hoc; residual discordances—including type C injuries without a coded dislocation—therefore reflect the wording of the source documents rather than an inconsistency in the definition of either variable.

Therapeutic modalities—surgical indication, type of treatment, surgical approach, time to surgery—were collected for descriptive purposes. They were not subjected to any analysis of association with AOSpine type: the surgical indication could not be dissociated retrospectively from the procedure actually performed, and both the use of fusion and the surgical approach apply by construction only to operated patients. The use of fusion was ascertained from the wording of the procedure recorded in the operative report. Neurological recovery was defined as a gain of at least one ASIA grade between admission and the last documented assessment; in-hospital mortality was the vital endpoint.

All records underwent source verification—inpatient chart, imaging and operative report—covering the analysed variables: AOSpine type, ASIA grade on admission and at the last assessment, injury level, age, vital status and therapeutic modalities. After this verification, these variables were documented for all 366 patients; no data were missing and no imputation was required. Outcome analyses were performed on documented survivors.

2.3. Ethical Considerations

This study was conducted in accordance with the principles of the Declaration of Helsinki. The protocol was approved by the Institutional Ethics Committee of Bouaké Teaching Hospital (approval No. CEI/CHU-BKE/102/2026), which determined that individual written consent was not required for the retrospective analysis of anonymised routine care data. For the prospective phase, informed consent was obtained from patients or their legal representatives. Data from the retrospective phase were anonymised before analysis in accordance with the department’s internal procedures.

2.4. Statistical Analysis

Qualitative variables are expressed as counts and percentages, and quantitative variables as the median with the interquartile range given in parentheses. Asso-

ciations between AOSpine type and categorical variables were tested using the chi-square test, replaced by the Fisher-Freeman-Halton exact test when an expected count was below 5. The neurological severity endpoint was analysed according to a prespecified plan: the primary test concerned the full distribution of ASIA grades (3×5 table). The frequency of complete injuries (ASIA A) constituted an exploratory secondary comparison, whose p-value was adjusted for multiple comparisons (Bonferroni correction) and complemented by a Cochran-Armitage test for trend (ordered types $A < B < C$). The family of comparisons subjected to the Bonferroni correction comprised exactly two secondary tests—the comparison of the frequency of ASIA A across types and the test for trend—whose nominal p-values were therefore multiplied by two; the primary 3×5 test was not part of this family.

Two multivariable logistic regression models (reference category: type A) were built: in-hospital mortality (adjusted for ASIA A, cervical level, age) and neurological recovery among survivors with an initial deficit (ASIA A - D; adjusted for ASIA A/B, cervical level, age). Adjustment variables were selected a priori on the basis of their clinical relevance and their potential role as confounders. A stratified analysis compared the cervical and thoracolumbar strata. Discrimination was assessed using the area under the receiver operating characteristic (ROC) curve, or AUC. The 95% confidence intervals (CI) of the AUCs were computed by stratified bootstrap with 2000 resamples. Calibration was assessed using the calibration intercept and slope; optimism-corrected estimates were obtained by bootstrap with 1000 resamples.

The main estimand of this study was the direct association between AOSpine morphological type and each outcome, conditional on admission ASIA grade, injury level and age; the incremental predictive performance of the classification was assessed separately as a secondary analysis. Because the admission ASIA grade may lie on the causal pathway between injury morphology and neurological outcome, the adjusted estimates should be read as conditional associations rather than as total effects; no formal mediation analysis was performed, and bivariate associations that weakened after adjustment are described as attenuated after adjustment rather than as mediated.

The ASIA grade was dichotomised differently in the two models on a priori clinical grounds and to preserve an adequate number of events per variable. In the mortality model, the contrast of interest was complete versus incomplete injury (ASIA A versus B - E), complete injury being the strongest established determinant of early death. In the recovery model, restricted to patients with an initial deficit (grades A - D), the contrast opposed severe (A/B) to moderate (C/D) impairment, grades C and D carrying a recognised higher potential for recovery. With 64 deaths and 120 recovery events, retaining the five individual grades would have added several parameters per model and produced sparse categories.

Three complementary analyses were added. A sensitivity analysis retaining the five individual ASIA grades (A to E) was performed to verify the robustness of the results obtained with the prespecified dichotomisations. In the stratified analyses, adjusted odds ratios and their 95% confidence intervals were estimated within each segment by logistic regression, with type A as the reference. Finally, the incremen-

tal predictive contribution of AOSpine type was assessed by comparing, for each outcome, a base model (ASIA grade, cervical level, age) with an extended model adding AOSpine types B and C, using the apparent and optimism-corrected AUC, the corrected difference in AUC (Δ AUC), the calibration parameters and a likelihood ratio test.

For the primary endpoints, differences in proportions between types are reported with their 95% confidence intervals, in order to bound the effect sizes compatible with the data rather than to conclude from a single absence of statistical significance. Given the observational design of the study, results are presented in terms of association and not causation. The significance threshold was set at 0.05. Analyses were performed using Python 3.12 (pandas, statsmodels, scikit-learn).

3. Results

3.1. Characteristics of the Population

The median age of the 366 patients was 35 years (27 - 46). The cohort comprised 296 men (80.9%) and 70 women (19.1%), giving a male-to-female ratio of 4.2. Road traffic collisions were the leading injury mechanism (229 patients, 62.6%), ahead of falls (95; 26.0%) and assaults (20; 5.5%); occupational injuries, sports injuries and other mechanisms together accounted for 22 cases (6.0%). Two hundred and sixty-three patients (71.9%) had been referred from another facility and 103 (28.1%) were admitted directly.

3.2. Distribution of the AOSpine Classification

Among the 366 patients, injuries were type A in 127 patients (34.7%), type B in 80 (21.9%) and type C in 159 (43.4%) (**Table 1**; **Figure 1**). Cervical involvement predominated (183 patients, 50.0%) and did not differ significantly across AOSpine types (55.1%, 53.8% and 44.0% of types A, B and C; $p = 0.13$). With regard to treatment, 345 patients (94.3%) underwent surgery and 21 (5.7%) were managed conservatively; fusion was performed in 281 of the 345 operated patients (81.4%), through a posterior approach in 244 cases (70.7%), an anterior approach in 71 (20.6%) and a combined approach in 30 (8.7%); the median time to surgery was 3 days (2 - 4). These data are reported descriptively and were not subjected to comparative analysis by AOSpine type.

3.3. AOSpine and Injury Characteristics: Mechanical Consistency

AOSpine type was strongly associated with the mechanical markers of the injury (**Table 2**). All type B and type C injuries were classified as unstable, compared with 21.3% of type A injuries. This association is definitional—instability is intrinsic to tension band and translation injuries—and is reported only as a check of the internal consistency of the coding; no statistical test is applied to it. The three markers that follow, by contrast, do not derive from the definition of the types. Dislocation was more frequent in type C injuries (88.7%) than in types A (35.4%) and B (30.0%) ($p < 0.001$), consistent with the translation mechanism. The eighteen type C injuries without a coded dislocation reflect the independent abstraction of

the two variables from the source documents (Section 2.2). Disco-ligamentous injury was characterised by types B (82.5%) and C (64.2%), compared with 19.7% of type A injuries ($p < 0.001$). Spinal cord compression followed an increasing gradient from type A (55.9%) to type C (83.6%) ($p < 0.001$).

Table 1. Distribution of the AOSpine classification and spinal segment involved ($n = 366$).

AOSpine type	n (%)	Distribution by segment (n)
Type A (compression)	127 (34.7%)	Cervical 70 · Thoracic 38 · Lumbar 14 · Sacral 5
Type B (tension band)	80 (21.9%)	Cervical 43 · Thoracic 24 · Lumbar 9 · Sacral 4
Type C (translation)	159 (43.4%)	Cervical 70 · Thoracic 62 · Lumbar 25 · Sacral 2
Total	366 (100%)	Cervical 183 · Thoracic 124 · Lumbar 48 · Sacral 11

AOSpine: morphological classification of traumatic spinal injuries of the AO Spine Knowledge Forum Trauma; type A: compression; type B: tension band injury; type C: translation. Percentages are calculated on the total cohort.

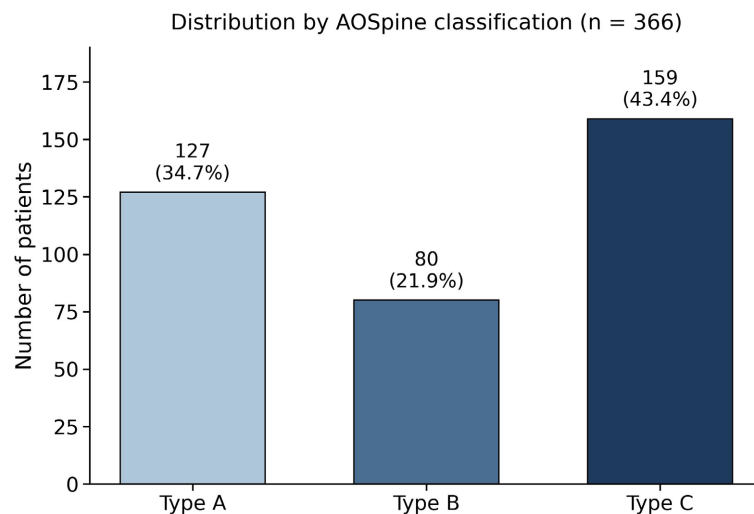


Figure 1. Distribution of the 366 patients by AOSpine morphological type (type A: compression; type B: tension band injury; type C: translation).

Table 2. AOSpine classification and injury characteristics ($n = 366$).

Injury characteristic	Type A	Type B	Type C	p-value
Instability [†]	21.3%	100%	100%	—
Dislocation	35.4%	30.0%	88.7%	<0.001
Disco-ligamentous injury	19.7%	82.5%	64.2%	<0.001
Spinal cord compression	55.9%	75.0%	83.6%	<0.001

Percentages are calculated by row on the number of patients in each type (type A: 127; type B: 80; type C: 159). Chi-square test. [†]Definitional association: instability is intrinsic to types B and C; this row is reported as a check of the internal consistency of the coding and is not tested. Dislocation denotes any vertebral malalignment demonstrated on imaging and is not equivalent to type C, which implies true translation.

3.4. AOSpine and Neurological Severity

In contrast with the mechanical markers, neurological severity was weakly related to AOSpine type. The primary test, based on the full distribution of ASIA grades on admission, was not significant (chi-square = 10.67; df = 8; $p = 0.221$). In the secondary analysis, the proportion of complete ASIA A injuries increased from type A to type C: 31.5% (40/127), 40.0% (32/80) and 47.2% (75/159). The overall comparison of ASIA A versus ASIA B-E was significant in the nominal analysis (chi-square = 7.22; $p = 0.027$) but did not persist after Bonferroni correction (adjusted $p = 0.054$). Conversely, the test for ordered trend remained significant after the same correction (Cochran-Armitage $z = 2.685$; nominal $p = 0.007$; adjusted $p = 0.015$). These findings indicate that osseo-disco-ligamentous morphology does not determine the overall distribution of ASIA grades, but that a gradient of complete injuries accompanies increasing morphological severity, consistent with the greater energy of translation mechanisms. This gradient on admission does not imply independent prognostic value, which is examined below.

3.5. AOSpine and Outcome

AOSpine type was associated neither with in-hospital mortality nor with neurological recovery (**Table 3**). In-hospital mortality was comparable across the three types (18.1%, 15.0% and 18.2% for types A, B and C; $p = 0.80$), the difference between types C and A being +0.1 percentage point (95% CI: -8.9 to +9.1). Three of the 64 deaths occurred in patients without an initial neurological deficit (ASIA E). Among the 262 survivors with an initial deficit (ASIA A - D), recovery (gain ≥ 1 ASIA grade) did not differ across AOSpine types (52.3%, 41.0% and 43.4%; $p = 0.31$), the difference between types C and A being -8.9 percentage points (95% CI: -22.8 to +5.0). Given these numbers, the study had 80% power to detect a difference of about 15 percentage points in mortality and 19 percentage points in recovery; the data rule out medium to large effects but remain compatible with a modest effect. Likewise, the occurrence of a documented complication ($p = 0.60$) and the need for revision surgery among operated patients (4.6%, 6.2% and 4.5%; $p =$

Table 3. AOSpine classification and in-hospital outcome.

Endpoint	Type A	Type B	Type C	p-value
In-hospital mortality	18.1%	15.0%	18.2%	0.80
Neurological recovery [‡]	52.3%	41.0%	43.4%	0.31
Documented complication	56.7%	63.8%	59.1%	0.60
Revision surgery [§]	4.6%	6.2%	4.5%	0.81

Chi-square test, except for the “revision surgery” row, where the minimum expected count was below five: Fisher-Freeman-Halton exact test. [§]Revision surgery presupposes a first procedure: this row is reported among the 345 operated patients (109 type A, 80 type B and 156 type C). [‡]Neurological recovery is defined as a gain of at least one grade on the ASIA (American Spinal Injury Association Impairment Scale), among the 262 survivors with an initial deficit (grades A to D). In-hospital mortality and the occurrence of a complication relate to all 366 patients.

0.81, Fisher-Freeman-Halton exact test) were independent of AOSpine type. The absence of any detectable association between osseo-disco-ligamentous morphology and outcome is in itself a noteworthy finding, suggesting that the clinical value of AOSpine lies in the standardised description of the injury rather than in the prediction of neurological outcome.

3.6. Multivariable Analyses

In multivariable analysis, no AOSpine type was independently associated with mortality or with recovery after adjustment (Table 4 and Table 5; Figure 2). In the mortality model, only ASIA grade A remained strongly associated with death (adjusted odds ratio 11.34; 95% CI: 5.62 - 22.88). Discrimination was acceptable (AUC 0.785; bootstrap 95% CI: 0.734 - 0.854). After bootstrap correction, the calibration intercept was -0.079 (95% CI: -0.433 to 0.399) and the slope was 0.922 (95% CI: 0.677 - 1.219). In the recovery model, severe initial impairment (ASIA A/B) reduced the probability of recovery (adjusted odds ratio 0.49; 95% CI: 0.30 - 0.82), with no independent effect of AOSpine type. Discrimination was modest (AUC 0.623; bootstrap 95% CI: 0.582 - 0.707); the corrected intercept was -0.041 (95% CI: -0.227 to 0.196) and the slope 0.756 (95% CI: 0.457 - 1.229), suggesting possible overfitting and less stable calibration. In a sensitivity analysis retaining the five individual ASIA grades, AOSpine types B and C showed no robust independent association with either outcome, and prognostic information remained carried chiefly by initial neurological severity: the overall conclusion was unchanged.

Table 4. Factors associated with in-hospital mortality: multivariable logistic regression.

Variable	Adjusted odds ratio	95% confidence interval	p-value
AOSpine B (ref. A)	0.68	0.29 - 1.61	0.382
AOSpine C (ref. A)	0.73	0.37 - 1.43	0.355
ASIA A (complete injury)	11.34	5.62 - 22.88	<0.001
Cervical level	1.70	0.93 - 3.13	0.086
Age (per year)	0.98	0.96 - 1.01	0.132

Model based on all 366 patients, 64 deaths, *i.e.*, 12.8 events per variable. Reference category: AOSpine type A. Area under the receiver operating characteristic (ROC) curve: 0.785 (bootstrap 95% confidence interval: 0.734 to 0.854). Bootstrap-corrected calibration: intercept -0.079 (-0.433 to 0.399), slope 0.922 (0.677 to 1.219). ASIA: American Spinal Injury Association Impairment Scale; ref.: reference category.

Table 5. Factors associated with neurological recovery: multivariable logistic regression.

Variable	Adjusted odds ratio	95% confidence interval	p-value
AOSpine B (ref. A)	0.70	0.36 - 1.39	0.313
AOSpine C (ref. A)	0.84	0.47 - 1.51	0.562
ASIA A/B (severe impairment)	0.49	0.30 - 0.82	0.007

Continued

Cervical level	1.33	0.80 - 2.21	0.275
Age (per year)	1.00	0.98 - 1.01	0.624

Model based on the 262 survivors with an initial neurological deficit (ASIA grades A to D), 120 recoveries, *i.e.*, 24.0 events per variable. Reference category: AOSpine type A. Area under the receiver operating characteristic (ROC) curve: 0.623 (bootstrap 95% confidence interval: 0.582 to 0.707). Bootstrap-corrected calibration: intercept -0.041 (-0.227 to 0.196), slope 0.756 (0.457 to 1.229). ASIA: American Spinal Injury Association Impairment Scale; ref.: reference category.

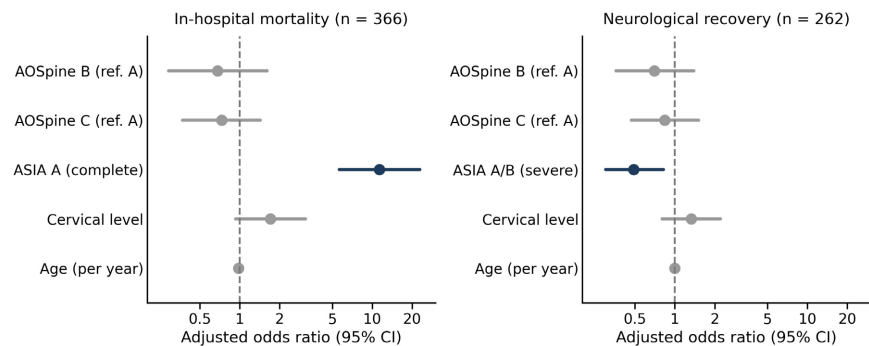


Figure 2. Adjusted odds ratios with 95% confidence intervals from the two multivariable logistic regression models: in-hospital mortality (366 patients) and neurological recovery (262 patients). The dashed line indicates an odds ratio of 1.

3.7. Stratified Analysis: Cervical versus Thoracolumbar

The analysis stratified by injured segment (cervical, $n = 183$; thoracolumbar, $n = 183$) provides further insight (**Table 6**). Mortality did not differ across AOSpine types in either stratum (cervical $p = 0.50$; thoracolumbar $p = 0.51$). At the cervical level, however, a bivariate gradient of recovery was apparent (type A 64.7%, B 48.5%, C 36.4%; $p = 0.02$); this gradient was nevertheless attenuated after adjustment for ASIA grade (adjusted odds ratio of type C 0.45, 95% confidence interval 0.18 to 1.15), indicating that it was attenuated after adjustment for neurological severity and was therefore not independently attributable to osseo-disco-ligamentous morphology. At the thoracolumbar level, recovery did not differ ($p = 0.25$). In both strata, the adjusted odds ratios of types B and C had wide confidence intervals crossing unity (**Table 6**).

3.8. Incremental Predictive Value of AOSpine Type

The direct comparison of models with and without AOSpine type is summarised in **Table 7**. For in-hospital mortality, adding AOSpine types B and C to the base model increased the apparent AUC from 0.773 to 0.785 and the optimism-corrected AUC from 0.760 to 0.772 (corrected Δ AUC +0.011); the likelihood ratio test did not favour the extended model (LR = 2.51; $p = 0.286$). For neurological recovery, the apparent AUC increased from 0.617 to 0.623 while the optimism-corrected AUC decreased from 0.596 to 0.585 (corrected Δ AUC -0.011 ; LR = 1.69; $p = 0.430$),

indicating that the apparent gain reflected model optimism. Calibration was not substantially modified by the addition of AOSpine type; the bootstrap-corrected calibration parameters of the extended models are those reported in **Table 4** and **Table 5**. These comparisons complement the regression estimates: beyond the non-significance of the individual coefficients, AOSpine type provided no detectable incremental prognostic information over initial neurological severity.

Table 6. Outcome by AOSpine type, stratified by spinal segment: crude proportions and adjusted odds ratios.

Endpoint/stratum	Type A	Type B	Type C	Adjusted OR, type B (95% CI)	Adjusted OR, type C (95% CI)
Mortality—cervical	15.7%	16.3%	22.9%	0.58 (0.18 - 1.89)	0.55 (0.20 - 1.53)
Mortality—thoracolumbar	21.1%	13.5%	14.6%	0.51 (0.14 - 1.80)	0.84 (0.31 - 2.25)
Recovery ^s —cervical	64.7%	48.5%	36.4%	0.57 (0.22 - 1.48)	0.45 (0.18 - 1.15)
Recovery ^s —thoracolumbar	35.1%	32.1%	47.8%	0.80 (0.28 - 2.30)	1.44 (0.60 - 3.44)

Cervical stratum: 183 patients; thoracolumbar stratum: 183 patients, including the eleven sacral injuries. Crude proportions by AOSpine type; adjusted odds ratios (OR) estimated by logistic regression within each stratum, with type A as the reference and the same adjustment variables as the main models except the injury level, which is fixed within each stratum. ^sThe denominators for recovery are the survivors with an initial deficit (128 at the cervical level, 134 at the thoracolumbar level). The cervical gradient of recovery was significant in bivariate analysis ($p = 0.02$) but attenuated after adjustment for the grade on the ASIA (American Spinal Injury Association Impairment Scale). Mortality: $p = 0.50$ at the cervical level and $p = 0.51$ at the thoracolumbar level. CI: confidence interval.

Table 7. Predictive performance of the multivariable models with and without AOSpine type.

Outcome	Model	Apparent AUC	Corrected AUC	Δ AUC [†]	Likelihood ratio test
In-hospital mortality	Base (ASIA A, cervical level, age)	0.773	0.760	—	—
	Extended (+ AOSpine B and C)	0.785	0.772	+0.011	LR = 2.51; $p = 0.286$
Neurological recovery	Base (ASIA A/B, cervical level, age)	0.617	0.596	—	—
	Extended (+ AOSpine B and C)	0.623	0.585	−0.011	LR = 1.69; $p = 0.430$

AUC: area under the receiver operating characteristic curve; corrected: optimism-corrected by bootstrap. [†] Δ AUC: difference in optimism-corrected AUC between the extended and the base model. LR: likelihood ratio statistic (2 degrees of freedom). Mortality models: 366 patients, 64 deaths; recovery models: 262 survivors with an initial deficit, 120 recoveries. The addition of AOSpine type did not substantially modify calibration.

4. Discussion

4.1. Main Finding

In this Ivorian cohort of 366 patients, the AOSpine classification behaved as a de-

descriptor of the mechanical severity of the injury and not as a neurological prognostic marker. AOSpine type was closely related to osseo-disco-ligamentous characteristics—dislocation, disco-ligamentous injury, spinal cord compression—and a gradient of complete neurological injuries accompanied increasing morphological severity. It did not, however, determine the overall distribution of ASIA grades and no association with mortality or with recovery was detected; after adjustment, only ASIA grade retained prognostic value. The direct comparison of models with and without AOSpine type confirmed the absence of a substantial incremental predictive gain, and the sensitivity analysis retaining the individual ASIA grades left these conclusions unchanged. The two classifications therefore measure distinct and non-redundant dimensions: involvement of the spinal column for one, involvement of the spinal cord for the other.

4.2. Why Was No Independent Prognostic Association of Morphology Detected?

The AOSpine classification is not a cause of outcome: it is a structured summary of lesion morphology, itself determined by the energy of the trauma and the biomechanics of the injury (energy → biomechanics → morphology → decision to stabilise). Functional recovery, however, depends chiefly on secondary spinal cord injury—inflammatory cascade, ischaemia, oedema, demyelination and then plasticity phenomena—which is not captured by a bone-based classification [1]. A translation injury (type C) may thus mechanically mandate fixation while partially sparing the spinal cord, whereas a severe cord contusion may complicate a bone injury of apparently moderate severity. The absence of a gradient of ASIA severity across AOSpine types, and the attenuation of the cervical gradient of recovery after adjustment, illustrate this independence: prognosis is carried by spinal cord involvement, captured by ASIA, and not by osseo-disco-ligamentous morphology.

4.3. Comparison with the International Literature

The AOSpine classification was developed by the AO Spine Knowledge Forum Trauma to standardise the description of injuries and to guide surgical strategy [6] [7]. Its inter- and intra-observer reliability has been validated internationally, both at the thoracolumbar [20]-[22] and at the cervical level [23], and derived severity scores (TL AOSIS, subaxial cervical score) have been proposed to formalise the surgical algorithm [8]-[10]. Our data do not allow this decision-making role to be assessed, since therapeutic modalities could not be analysed independently of the procedure performed; they address the descriptive and prognostic dimension of the classification. With regard to neurological prognosis, however, our results are consistent with those of Mushlin *et al.*, who reported a relationship between cervical morphology, severity on admission and outcome, but whose morphological effect was largely attenuated after adjustment for initial neurological impairment [16]. Our observations also fit within recommendations favouring early decompression and standardised neurological assessment [13]-[15]: the added value

of AOSpine lies upstream, at the time of the decision to stabilise, whereas the estimation of outcome rests on ASIA.

4.4. Comparison with African Series

Published African cohorts help to place these observations in context. The Hawassa series (Ethiopia, 252 patients) is the most directly comparable: its morphological distribution is close to ours (type A 39.7%, B 21.0%, C 39.3%) and AO type is strongly associated with neurological severity in bivariate analysis (Cramér's V 0.358; $p < 0.001$), yet no AO type retains an independent association with 30-day mortality after adjustment (type B adjusted odds ratio 0.50; type C 1.00), only complete injury (6.49) and cervicothoracic location (5.84) remaining significant [24]. That work therefore replicates our main finding in an independent cohort and in a comparable health system. East African series report converging profiles—tertiary referral recruitment, prolonged prehospital delays, high in-hospital mortality [25]–[27]—and show that the decision to operate is largely constrained by implant availability and by the patient's ability to pay, beyond lesion morphology alone [28]. French-speaking series from Cameroon [29], Kinshasa [30] and Senegal [31] report the same predominance of young men and the same weight of road traffic collisions. Our operative rate (94.3%) contrasts sharply, however, with that of these series—125 of 270 patients operated on in Tanzania [28], 34.5% in Hawassa [24]—where forgoing surgery is largely determined by the cost of implants and by families' ability to pay. This difference, which was not the subject of a comparative analysis here, would warrant prospective documentation. The continental meta-analysis by Darko *et al.* confirms the heterogeneity of surgical practice and the scarcity of multivariable analyses in these settings [2]. Our cohort is nevertheless distinguished by a high proportion of type C injuries (43.4%), higher than in series in which type A predominates; this feature probably reflects recruitment at a tertiary referral centre and should be taken into account in any comparison.

4.5. Clinical Implications

These results argue for the joint and convergent use of the two classifications: AOSpine to standardise the morphological description of the injury and communication between teams, ASIA for prognostic assessment, information given to the family and follow-up. Neither can substitute for the other. Systematic documentation of both parameters, feasible even without advanced imaging, provides a minimum foundation for building comparable registries and for assessing quality of care. The median time to surgery of three days is a further reminder that the main levers for improvement remain organisational—early referral, medicalised transport, access to imaging—rather than strictly morphological.

4.6. Conceptual Synthesis

The two classifications differ in their object—osseo-disco-ligamentous morphol-

ogy for AOSpine, spinal cord function for ASIA—in the moment at which they are used—lesion diagnosis on imaging for the former, admission and follow-up for the latter—and in their clinical contribution: describing and communicating the injury on the one hand, estimating outcome and informing the family on the other. In the present cohort, no independent prognostic association of AOSpine was detected after adjustment, whereas ASIA grade remained the main determinant.

4.7. Related Manuscript

This cohort is the subject of a second manuscript, devoted to the factors associated with in-hospital mortality and neurological recovery and to the care pathway. Both works concern the same population of 366 patients and share the descriptive tables, the primary endpoint and the multivariable regression models: the findings they have in common therefore do not constitute independent replications. They differ in their objective—here the prognostic value of the morphological classification in its own right, there the epidemiology, the care pathway and the clinical determinants of outcome—and in the variables they analyse. The present manuscript reproduces no AOSpine analysis appearing in the related manuscript, and vice versa.

4.8. Strengths and Limitations

The strengths of this work are the size of the cohort, the use of standardised classifications, the multivariable approach with bootstrap assessment of discrimination and calibration, the analysis stratified by segment and the presentation of effects as confidence intervals.

Several limitations must be underlined. First, the AOSpine thoracolumbar [6] and subaxial cervical [7] systems are distinct and were here grouped according to A/B/C morphology; this harmonisation, necessary for pooled analysis, together with the grouping of subtypes A1 - A4 and B1 - B3, entails a loss of information and may attenuate certain associations—the stratified analysis was intended to limit this effect. Second, no formal assessment of inter-observer agreement of the classification was performed, which may introduce measurement variability. The residual discordance between the coded dislocation and the type C assignment (18 of the 159 type C injuries had no coded dislocation) illustrates this variability. Non-differential misclassification of AOSpine type—that is, independent of outcome—would bias the observed associations towards the null and could therefore contribute to the null prognostic finding [32].

Third, no analysis of the association between AOSpine type and therapeutic modalities was conducted. The surgical indication could not be dissociated retrospectively from the procedure performed—the 345 indications correspond to the 345 operated patients—so that such an analysis would have been circular; moreover, the use of fusion and the surgical approach apply by construction only to operated patients, and comparing them across the whole cohort would produce a

denominator artefact. The decision to operate also depends on the surgeon and on the availability of the technical platform, without formalised standardisation. The contribution of AOSpine to surgical strategy therefore remains an open question, requiring prospective collection of the indication independently of the procedure performed.

Fourth, the spread of the cohort across a retrospective phase (2017-2021) and a prospective phase (January 2025-June 2026) exposes the study to a period effect: changes in surgical practice, in the team's experience and in the implants available may have influenced some decisions. Fifth, since instability is defined in part from AOSpine type, the corresponding association amounts to a check of internal consistency. Sixth, the sample size allowed only a difference of about 15 percentage points in mortality and 19 percentage points in recovery to be detected with 80% power; the confidence intervals of the differences between types C and A (mortality -8.9 to $+9.1$ percentage points; recovery -22.8 to $+5.0$ percentage points) rule out medium to large effects but remain compatible with a modest effect that could be clinically relevant. The absence of a prognostic association should therefore be read as the absence of an effect detectable at this sample size, and not as proof of equivalence.

Finally, the single-centre and partly retrospective design, together with the heterogeneity of follow-up duration (median 45 days, 14 - 180, range 1 - 365 days), the absence of standardised long-term functional follow-up (12 - 24 months) and the unavailability of the neurological modifiers (N0 - N4) and of detailed spinal cord imaging data, limit the prognostic scope of the analysis. These results should be interpreted in the context of a health system in which transfer delays, implant availability and access to magnetic resonance imaging may influence therapeutic strategy. Conversely, individual source verification of all records, with no missing data on the analysed variables, limits the risk of selection bias related to the exclusion of incomplete cases. The corrected calibration slope of the recovery model (0.756) and its wide confidence interval further indicate limited predictive stability, consistent with the absence of important variables such as spinal cord imaging data, the actual time to decompression and the intensity of rehabilitation. Lastly, apart from the sensitivity analysis retaining the individual ASIA grades and the comparison of models with and without AOSpine type, the results rest on a single definition of each endpoint and were not tested against alternative definitions, notably a recovery threshold of two ASIA grades or the exclusion of sacral injuries from the thoracolumbar stratum.

4.9. Perspectives

Future work should incorporate the neurological and stability modifiers of AOSpine, the derived severity scores [8] [9] and spinal cord imaging data, in order to assess whether a finer morphological characterisation adds prognostic value beyond ASIA grade. An inter-observer agreement study and multicentre validation would clarify the reproducibility of these observations in other West African settings. The

findings of this cohort suggest that the complementarity between AOSpine and ASIA could provide a relevant decision-making framework beyond the West African context, subject to multicentre validation.

5. Conclusion

In this Ivorian cohort of 366 patients, the AOSpine classification is a robust tool for characterising the mechanical severity of the injury. However, no independent prognostic contribution and no substantial incremental predictive improvement of the AOSpine classification beyond initial neurological severity were detected, although modest effects cannot be excluded; ASIA grade remained the only variable associated with outcome. The joint use of AOSpine and ASIA thus appears to be the most appropriate approach to the management of traumatic spinal injuries in resource-limited settings. Morphological assessment and neurological assessment are not competing but synergistic; their combination is the cornerstone of modern management of traumatic spinal injuries.

Data Availability

The anonymised data used for this study are available from the corresponding author on reasonable request, subject to applicable ethical and regulatory requirements.

Reporting Compliance

The manuscript was prepared in accordance with the STROBE recommendations for observational studies; the completed STROBE checklist is provided as supplementary material. The study was not registered in advance in a registry of observational studies.

Related Manuscript

The authors declare that a second manuscript, submitted concurrently, is based on the same cohort of 366 patients. The two manuscripts share the basic descriptive data, several descriptive tables, the primary endpoint and the same multivariable logistic regression models. They therefore do not constitute two independent analyses. Their complementarity rests on distinct scientific objectives: the present work specifically assesses the independent prognostic value of the AOSpine classification, whereas the related manuscript analyses the epidemiology, the care pathway and the clinical determinants of outcome. A full copy of the related manuscript is enclosed with this submission in accordance with the ICMJE recommendations.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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