

Presentation, Management, and Outcomes of Thoracic, Thoracolumbar, and Lumbar Spine Trauma in East Africa: A Cohort Study

CHIBUIKEM A. IKWUEGBUENYI, MD^{1,2}; FRANÇOIS WATERKEYN, MD³; ARTHUR OKEMBO, MD²; COSTANSIA BURETA, MD, PhD²; KASSIM O. KASSIM, MD²; HAMISI K. SHABANI, MD, PhD²; SCOTT ZUCKERMAN, MD, MPH⁴; AND ROGER HÄRTL, MD¹

¹Department of Neurological Surgery, New York Presbyterian Hospital/Och Spine, Weill Cornell Medicine, New York, NY, USA; ²Division of Neurosurgery, Muhimbili Orthopedic and Neurosurgery Institute, Dar es Salaam, Tanzania; ³Department of Neurosciences, Grand Hôpital de Charleroi, Charleroi, Belgium; ⁴Departments of Neurological Surgery and Orthopedic Surgery, Vanderbilt University Medical Center, Nashville, TN, USA

ABSTRACT

Background: Trauma to the thoracic, thoracolumbar (TL), and lumbar spine is common and can cause disability and neurological deficits. Using a cohort of patients suffering from thoracic, TL, and lumbar spine trauma in a tertiary hospital in East Africa, the current study sought to: (1) describe demographics and operative treatment patterns, (2) assess neurologic outcomes, and (3) report predictors associated with undergoing surgery, neurologic improvement, and mortality.

Methods: A retrospective cohort study of patient records from September 2016 to December 2020 was conducted at a prominent East Africa referral center. The study collected data on demographics, injury, and operative characteristics. Surgical indications were assessed using the AO (*Arbeitsgemeinschaft für Osteosynthesefragen*) TL fracture classification system and neurological function. Logistic regression analysis identified predictors for operative treatment, neurologic improvement, and mortality.

Results: The study showed that 64.9% of the 257 TL spine trauma patients underwent surgery with a median postadmission day of 17.0. The mortality rate was 1.2%. Road traffic accidents caused 43.6% of the injuries. The most common fracture pattern was AO Type A fractures (78.6%). Laminectomy and posterolateral fusion were performed in 97.6% of the surgical cases. Patients without neurological deficits (OR: 0.27, 95% CI: 0.13–0.54, $P < 0.001$) and those with longer delays from injury to admission were less likely to have surgery (OR: 0.95, 95% CI: 0.92–0.99, $P = 0.007$). The neurologic improvement rate was 11.1%. Univariate analysis showed a significant association between surgery and neurologic improvement (OR: 3.83, 95% CI: 1.27–16.61, $P < 0.001$). However, this finding was lost in multivariate regression.

Conclusions: This study highlights various themes surrounding the management of TL spine trauma in a low-resource environment, including lower surgery rates, delays from admission to surgery, safe surgery with low mortality, and the potential for surgery to lead to neurologic improvement.

Clinical Relevance: Despite challenges such as surgical delays and limited resources in East Africa, there is potential for surgical intervention to improve neurologic outcomes in thoracic, TL, and lumbar spine trauma patients.

Level of Evidence: 4.

Other and Special Categories

Keywords: traumatic spinal cord injury, spine trauma, thoracolumbar, LMICs, Tanzania

INTRODUCTION

Traumatic spinal injury (TSI), which includes spinal column fractures and spinal cord injuries (SCIs), is a major global cause of disability and mortality.^{1,2} The incidence is higher in low- and middle-income countries (LMICs), at 13.69 per 100,000 people, than in high-income countries (HICs), at 8.72 per 100,000 people.³ Most patients with TSI require surgical intervention; however, surgery rates are low in LMICs due to limited access to health care, lack of trained personnel, financial barriers, limited infrastructure and resources,

and cultural and societal factors.² LMICs account for only 3.5% of the projected 234 million surgeries despite accounting for more than one-third of the global population.⁴ Furthermore, although urgent decompression and stabilization have been proven to improve neurologic outcomes in patients with SCI,^{5,6} this is yet to be translated in LMICs as the timing for surgery is still prolonged. In a 2022 systematic review conducted by Chanbour et al, it was revealed that the delay from the time of injury to reaching the operating room was approximately 36 hours longer in LMICs compared to HICs.² Such delays in surgical intervention can lead to

complications, prolonged hospital stays, and increased health care costs.⁷

Anatomically and functionally, the thoracolumbar (TL) spine refers to the region comprising the thoracic spine (T1-T10), the TL junction (T10-L2), and the lumbar spine (L3-L5).⁸ TL spine injuries are prevalent and can cause substantial disability, deformity, and neurological deficit.⁹ Approximately 50% to 60% of injuries to the TL region affect the transitional zone (T10-L2), while 25% to 40% involve the thoracic spine and 10% to 14% affect the lower lumbar spine and sacrum.¹⁰ These injuries are more common in young men aged 20 to 40 years, with motor vehicle accidents and fall from heights accounting for 65% of all cases.^{11,12}

Approximately 50% of TL injuries are considered unstable,⁹ and posttraumatic neurological deficits are common. The region involved and the fracture type determine the likelihood and severity of neurologic deficit. Due to its rigid structure, the thoracic spine has a high prevalence of neurological deficits because of its narrow spinal canal and the energy required to induce fractures in this region.¹³ Conversely, the lumbar spine has a lower incidence of neurological impairments due to the larger size of the neural canal and the greater resilience of the cauda equina nerve roots.¹³ In a multicenter study, the incidence of neurological deficit ranged from 22% to 51% depending on the fracture type (22% in type A, 28% in type B, and 51% in type C fractures), according to the AO classification, a system used to classify spine trauma with good reliability and using descriptive terms for each injury.^{14,15}

Despite significant advances in spinal imaging and management procedures over the past 2 decades, a shortage of rigorous clinical studies has contributed to a debate over the best management for patients with thoracic, TL, and lumbar spine injuries.¹⁶ Using a population of thoracic, TL, and lumbar spine trauma patients from a major East Africa referral center, our goals were to (1) describe demographics and operative treatment patterns, (2) assess neurologic outcomes, and (3) report predictors associated with undergoing surgery, neurologic improvement, and mortality among patients managed at a primary referral center for spine trauma in Tanzania.

METHODS

Study Design and Clinical Setting

We retrospectively analyzed prospectively collected data from the Muhimbili Orthopedic Institute (MOI), a major referral hospital in Dar es Salaam, Tanzania.

MOI houses 380 general ward beds, 18 intensive care unit beds, 16 high dependency unit beds, 10 emergency department beds, and 9 operating rooms. Onsite imaging includes x-rays, computed tomography (CT), and magnetic resonance imaging (MRI). The local institutional review board approved the current study, and informed consent was obtained from all patients.

Patient Identification

All consecutive patients admitted for TSIs at the thoracic, TL, and lumbar levels from September 2016 to December 2020 (52 months) were included. Exclusion criteria included those <14 years old and those with moderate or severe traumatic brain injury. Additionally, we excluded patients with C-spine injuries or fractures.

Clinical and Operative Data

Several demographic and injury-specific data points were collected, including age, gender, and mechanism of injury. Injury levels were categorized according to prior studies.¹⁷ Due to the difficulty in deciphering the extent of decompression, this variable was kept binary (yes/no). Insurance status was classified as public (had to provide all funds before receiving hospital services) or private (no additional funds required to receive hospital services).

Classification of Fractures, Neurologic Status, Surgery, and Timing

We classified fractures according to the AO TL classification.¹⁸ If applicable, we also documented the degree of listhesis by using the following classification: Grade I = 25% of listhesis, Grade II = 50%, Grade III = 75%, and Grade IV = 100%. Spondyloptosis had a listhesis of >100%.¹⁹ Neurological examinations were obtained on admission and discharge, according to the American Spinal Injury Association (ASIA) Impairment Scale.²⁰ The type of surgery was classified into 2 groups:

1. Posterior laminectomy and fusion with pedicle screws.
2. Decompression only.

We recorded time in days for the following time points: injury to admission, admission to the operating room, and total length of stay.

Surgical Indication

All patients were retrospectively reviewed by a team of 2 individuals (a neurosurgery trainee and a consultant) to determine whether an indication for surgery was

present using a combination of the AO fracture classification system and neurologic function in accordance with prior studies.^{18,21} An injury was considered to have a surgical indication in 1 of 2 ways: (1) the fracture was considered unstable (AO type A4, B, or C) or (2) the fracture was potentially unstable, classified as A0-A3 but with neurologic impairment (ASIA A–D) and neurological compression confirmed by the imaging. Given the limited resources, some patients only had x-ray images available, and in these cases, the best estimation of fracture type was made.

Statistical Methods

All continuous data were presented as mean (SD) and/or median with interquartile range (IQR), whereas all count data were presented as *n* (%). Mann-Whitney *U* and χ^2 tests or the Fisher's exact test was used to assess differences among continuous and categorical variables, respectively. Univariate logistic regression, followed by multivariate logistic regression, was used to evaluate predictors of 3 outcomes: operative treatment, improvement in neurologic function, and mortality. Any variable with *P* < 0.10 after univariate regression was included in the multivariate model. The second outcome of improved neurologic function was

subdivided into a surgical group. The statistically significant level was set at 0.05, and statistical analysis was performed using R version 4.1.2 (Vienna, Austria).

RESULTS

Patient Demographics

During the study period, 257 patients were admitted to MOI with a TL spine injury. One hundred sixty-seven patients (64.9%) were treated operatively on a median (IQR) of the postadmission day 17.0 (7.0–30.0), whereas 90 were managed conservatively (Table 1).

The cohort's mean age was 35.2 years \pm 11.3, with the nonoperative group slightly older. Regarding the cohort of 257 patients, road traffic accidents were the most common injury mechanism, and most patients had public insurance (87.5%). Almost all patients were admitted to an outside hospital before MOI (99.2%), leading to a median time from injury to MOI admission of 3.0 days (IQR: 1.0–7.0). X-ray images were obtained for most patients (80.5%). The most common fracture pattern was compression fractures (AO type A) (*n* = 202, 78.6% of patients), and among them, burst fractures (AO type A4) were the most common subclassification (*n* = 157, 61.1% of patients), followed by

Table 1. Demographics, injury, and hospitalization information of patients with thoracic, thoracolumbar, and lumbar spine injuries.

Variable	Total <i>N</i> = 257	Operative <i>n</i> = 167	Nonoperative <i>n</i> = 90	<i>P</i>
Age, mean \pm SD, y	35.2 \pm 11.3	34.4 \pm 11.3	36.8 \pm 11.3	0.059
Sex, male, <i>n</i> (%)	215 (83.7)	137 (82)	78 (86.7)	0.435
Insurance, <i>n</i> (%)				0.819
Public	225 (87.5)	145 (86.8)	80 (88.9)	
Private	32 (12.5)	22 (13.2)	10 (11.1)	
Mechanism, <i>n</i> (%)				0.439
RTA	112 (43.6)	76 (45.5)	36 (40)	
Fall	95 (37.0)	57 (34.1)	38 (42.2)	
Other	50 (19.4)	34 (20.4)	16 (17.8)	
Admitted to OSH, <i>n</i> (%)	255 (99.2)	166 (99.4)	89 (98.9)	1.000
Location, <i>n</i> (%)				
Thoracic	52 (20.2)	34 (20.4)	18 (20)	1.000
Thoracolumbar junction (T10–L2)	189 (73.5)	126 (75.4)	63 (70)	0.425
Lumbar	16 (6.2)	7 (4.2)	9 (10)	0.116
Imaging, <i>n</i> (%)				
X-ray imaging	207 (80.5)	131 (78.4)	76 (84.4)	0.320
CT	80 (31.1)	55 (32.9)	25 (27.8)	0.477
MRI	152 (59.1)	101 (60.4)	51 (56.7)	0.719
Neurologic status, <i>n</i> (%)				
Complete (ASIA A)	117 (45.5)	80 (47.9)	37 (41.1)	0.362
Incomplete (ASIA B–D)	81 (31.5)	62 (37.1)	19 (21.1)	0.013
Intact (ASIA E)	59 (23)	25 (15.0)	34 (37.8)	< 0.001
Indication for surgery, <i>n</i> (%)	232 (90.3)	167 (100)	65 (72.2)	< 0.001
Length of stay, median (IQR), d	25 (14–43)	28 (15–45)	22.5 (11.2–41.8)	0.117
Time from injury to admission, median (IQR), d	3 (1–7)	3 (1–6)	3 (1–9.8)	0.755
Pressure ulcer, <i>n</i> (%) ^a	54 (21)	32 (19.2)	22 (24.4)	0.419
Mortality, <i>n</i> (%)	3 (1.2)	1 (0.6)	2 (2.2)	0.584

Abbreviations: ASIA, American Spinal Injury Association; CT, computed tomography; IQR, interquartile range; MRI, magnetic resonance imaging; OSH, outside hospital; RTA, road traffic accident.

^aOne missing value.

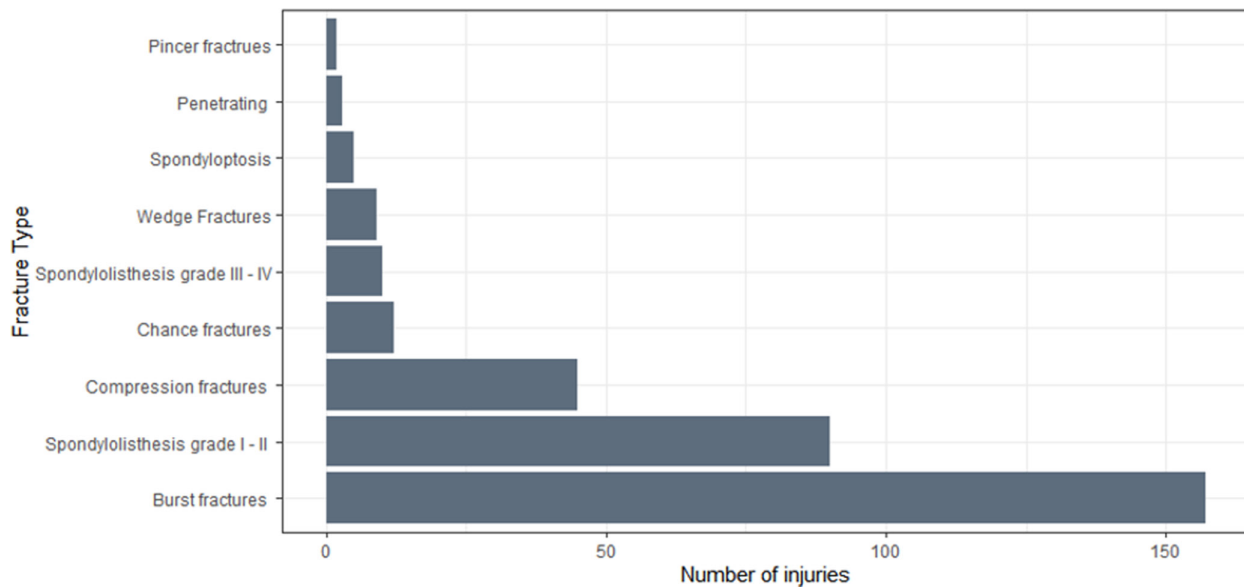


Figure 1. Fracture types among 257 thoracic, thoracolumbar, and lumbar spine trauma patients (each fracture type counted separately when more than 1 injury was present).

AO type C fractures associated with spondylolisthesis grade I/II ($n = 90$, 35.0% of patients). When comparing the operative and nonoperative groups, we noticed no difference in imaging between the 2 groups. Operative patients had more incomplete injuries, whereas nonoperative patients had more intact injuries. Interestingly, 72.2% of patients in the nonoperative group had an indication for surgery. Mortality was low in both groups, with 1 patient (0.6%) dying in the operative cohort and 2 (2.2%) in the nonoperative cohort (Figure 1).

Operative Variables

Approximately 232 thoracic, TL, and lumbar spine trauma patients (90.3%) had an indication for surgery, but only 167 patients (64.9% of the total sample; 71.9% of those with an operative indication) underwent to surgery. The 65 other patients (28% of those with an operative indication) did not undergo surgery despite the surgical indication. Of the 167 operative patients, posterolateral fusion (PLF) \pm laminectomy was the most common operation (97.6%); only 3 patients underwent decompression only (Table 2). The mean numbers of screws and levels fused were 5.6 ± 1.7 and 2.7 ± 1.1 , respectively, indicating that short-segment fusion was commonly done. A representative case of a surgically treated TL burst fracture is shown in Figure 2. The median time from admission to the operating room was 17.0 days (0–184). Approximately 52.6% of patients underwent postoperative imaging, almost exclusively radiography.

Neurologic Status

Of the 252 patients with an examination recorded at discharge (98%), most had no ASIA change ($n = 222$, 88.1%). Twenty-eight patients (11.1%) improved neurologically by at least 1 ASIA grade. Among them, the ASIA score at admission was A for 5 patients, B for 11 patients, C for 6 patients, and D for 6 patients (Table 3). Twenty-five of the patients (89%) who improved were in the operative group. Only 2 patients worsened in the cohort, 1 in each subgroup, and both with ASIA-B on admission (Table 4).

Predictors of Undergoing Surgery

Logistic regression was used to assess predictors of undergoing treatment. After univariable logistic regression, the following factors emerged as factors associated with reduced odds of undergoing surgical treatment: (1) having an ASIA A/E compared

Table 2. Operative details of those undergoing surgery.

Parameter	Value ($n = 167$)
Operation new, n (%) ^a	
Posterior fusion thoracic/lumbar	163 (97.6)
Decompression only	3 (1.8)
Screws, mean \pm SD	5.6 ± 1.7
Number of levels fused, mean \pm SD	2.7 ± 1.1
Postoperative imaging, n (%)	
X-ray imaging ^a	85 (50.9)
Computed tomography ^a	2 (1.2)
Magnetic resonance ^a	2 (1.2)

^aOne missing value.

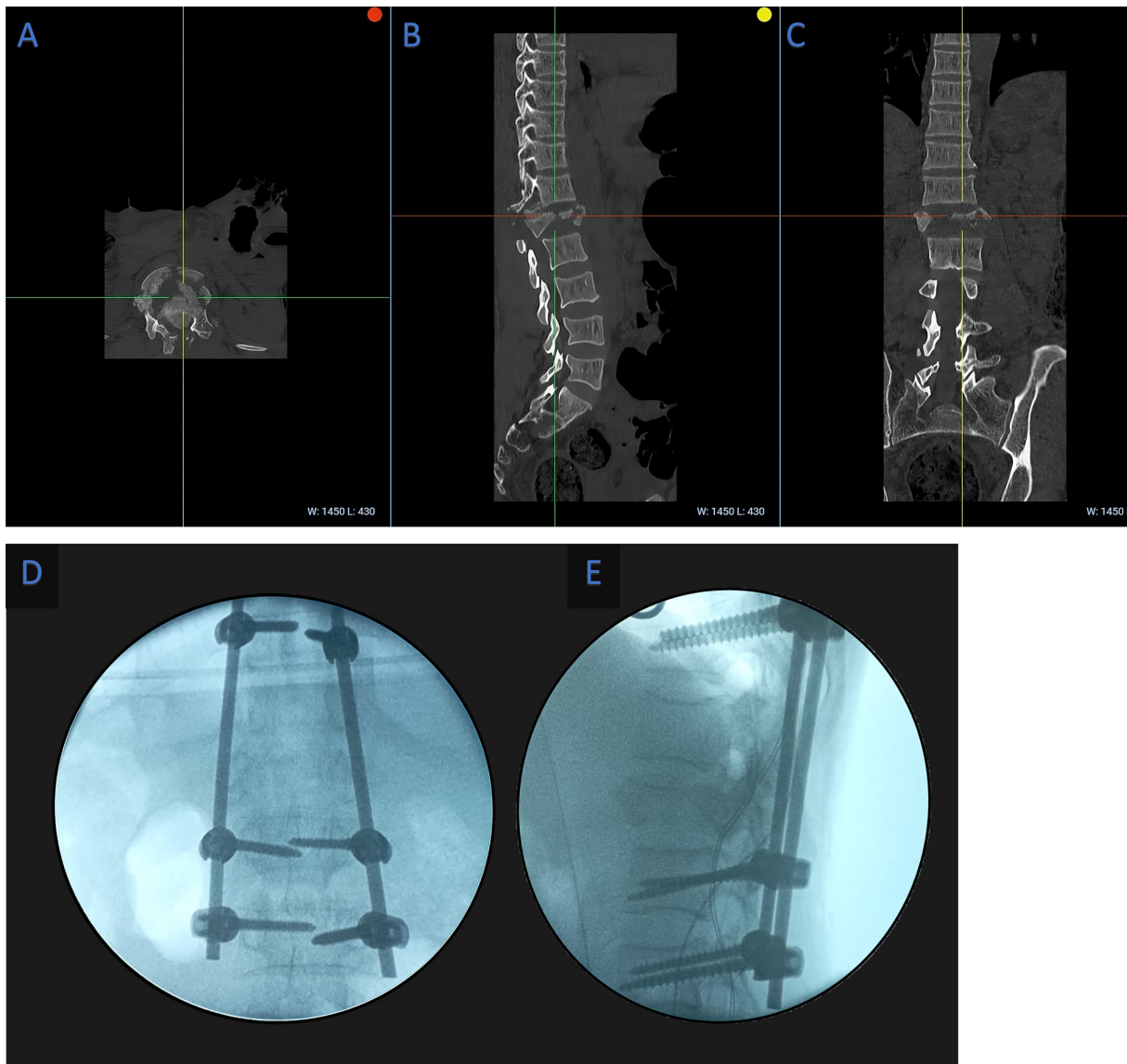


Figure 2. (A–C) Axial, sagittal, and coronal preoperative computed tomography images of a patient with L1 burst fracture. (D, E) Intraoperative x-ray anteroposterior and lateral views after instrumentation.

to an ASIA B-D (incomplete injury) (OR: 0.45, 95% CI: 0.25–0.81, $P = .009$); (2) having an intact injury (ASIA E) compared to complete or incomplete injury (ASIA A–D) (OR: 0.29, 95% CI: 0.16–0.53, $P < 0.001$); and (3) longer time from injury to

admission reduced the odds of getting surgery (OR: 0.97, 95% CI: 0.94–0.99, $P = 0.048$) (Table 5). Following multivariable logistic regression, 2 independent predictors of undergoing operative treatment emerged: (1) having an intact injury (ASIA E)

Table 3. Neurologic status: changes in ASIA score from admission to discharge

ASIA on Admission, n (%)	ASIA on Discharge, n (%)					Total
	A	B	C	D	E	
A	108	2	3	0	0	113 (44.8)
B	2	33	8	3	0	46 (18.3)
C	0	0	7	5	1	13 (5.2)
D	0	0	0	15	6	21 (8.3)
E	0	0	0	0	59	59 (23.4)
Total	110 (43.7)	35 (13.9)	18 (7.1)	23 (9.1)	66 (26.2)	252 (100)

Abbreviation: ASIA, American Spinal Injury Association.

Table 4. Neurologic status: classification of ASIA score changes, *n* (%).

Operative Status	Worsened	Stable	Improved
Operative (<i>n</i> = 163)	1 (0.6)	137 (84.0)	25 (15.3)
Nonoperative (<i>n</i> = 89)	1 (1.1)	85 (95.5)	3 (3.4)
Total (<i>n</i> = 252)	2 (0.8)	222 (88.1)	28 (11.1)

Abbreviation: ASIA, American Spinal Injury Association.

compared to complete or incomplete injury (ASIA A-D) (OR: 0.27, 95% CI: 0.13–0.54, $P < 0.001$) and (2) longer time from injury to admission reduced odds of getting surgery (OR: 0.95, 95% CI: 0.92–0.99, $P = 0.007$). Hence, patients with intact injuries and a longer duration before admission are less likely to undergo surgical intervention.

Predictors of Neurologic Improvement

After univariable logistic regression, the following factors emerged as predictors of neurologic improvement: (1) having an upper thoracic/lumbar injury compared to a lower thoracic injury (OR: 3.97, 95% CI: 1.67–10.56, $P = 0.002$); (2) having a lumbar injury rather than a thoracic injury (as indicated by the OR of 0.14 for thoracic injuries [95% CI: 0.05–0.33, $P < 0.001$], suggesting reduced odds of neurological improvement for thoracic injuries); (3) having surgical treatment compared to nonoperative treatment (OR: 3.83, 95% CI: 1.27–16.61, $P = 0.034$); and (4) having an incomplete injury compared to complete injury (OR: 8.71, 95% CI: 3.38–27.05, $P < 0.001$) (Table 6). However, following multivariable logistic regression, only 1 independent predictor

emerged: having an incomplete injury (ASIA B-D) compared to a complete injury (ASIA A) (OR: 5.74, 95% CI: 1.94–18.00, $P = 0.002$). In the subset of 138 patients who underwent surgery, univariable logistic regression showed that (1) patients with an upper thoracic/lumbar injury had higher odds of neurological improvement compared to those with a lower thoracic injury (OR: 3.36, 95% CI: 1.34–9.22, $P = .012$) and (2) patients with a thoracic injury were less likely to have neurological improvement compared to those with a lumbar injury (OR: 0.17, 95% CI: 0.06–0.42, $P < 0.001$). Following multivariable logistic regression, only 1 independent predictor emerged: patients with a thoracic injury were less likely to have a neurological improvement compared to those with a lumbar injury (OR: 0.09, 95% CI: 0.00–0.51, $P = 0.027$).

Predictors of Mortality

Only 3 patients in the cohort died—1 patient (0.6%) in the operative group and 2 (2.2%) in the nonoperative group—for an overall mortality rate of 1.2%. After regression analysis, no factor was significantly associated with increased odds of mortality. A trend for operative treatment being associated with reduced odds of mortality was seen, although statistical significance was not achieved (OR: 0.27, 95% CI: 0.01–2.80, $P = 0.281$) (Table 7).

Table 5. Predictors of operative treatment.

Variable	Univariable Logistic Regression		Multivariable Logistic Regression ^a	
	OR (95% CI)	<i>P</i>	OR (95% CI)	<i>P</i>
Age, continuous, y	0.98 (0.96, 1.00)	0.106	-	-
Age				
Young, <30 y (<i>n</i> = 91)	Reference	0.110	-	-
Old, ≥30 y (<i>n</i> = 166)	0.64 (0.36, 1.09)	-	-	-
Sex				
Female (<i>n</i> = 42)	Reference	0.339	-	-
Male (<i>n</i> = 215)	0.70 (0.33, 1.42)	-	-	-
Injury level				
Upper thoracic (<i>n</i> = 33)	Reference	-	-	-
Lower thoracic (<i>n</i> = 122)	1.22 (0.53, 2.69)	0.634	-	-
Lumbar (<i>n</i> = 102)	0.92 (0.40, 2.06)	0.847	-	-
Insurance				
Private (<i>n</i> = 32)	Reference	0.633	-	-
Public (<i>n</i> = 225)	0.82 (0.35, 1.78)	-	-	-
Neurologic Examination				
Complete: ASIA A (ref) vs B–E; (<i>n</i> = 117)	0.76 (0.45, 1.27)	0.297	-	-
Incomplete: ASIA B–D (ref) vs A/E; (<i>n</i> = 81)	0.45 (0.25, 0.81)	0.009	-	-
Intact: ASIA A–D (ref) vs E; (<i>n</i> = 59)	0.29 (0.16, 0.53)	<0.001	0.27 (0.13, 0.54)	<0.001
Time from injury to admission, continuous, d	0.97 (0.94, 0.99)	0.048	0.95 (0.92, 0.99)	0.007

Abbreviation: ASIA, American Spinal Injury Association.

^aMultivariable logistic regression analysis controlled for age, sex, and mechanism of injury.

Table 6. Predictors of neurologic improvement among all patients and operative patients. Multivariable logistic regression controlling for age, sex, admission neurologic exam, and level of injury.

Variable	Univariable Logistic Regression		Multivariable Logistic Regression	
	OR (95% CI)	P	OR (95% CI)	P
All patients, N = 193 ^a				
Age		0.432		-
Young, <30 y (n = 75)	Reference	-	-	-
Old, ≥30 y (n = 118)	0.71 (0.29, 1.63)	-	-	-
Sex		0.820		-
Female (n = 25)	Reference	-	-	-
Male (n = 168)	0.88 (0.30, 3.19)	-	-	-
Injury level				
Upper thoracic (ref) vs lower thoracic/lumbar (n = 29) ^b	5.52 (1.10, 100)	0.100	-	-
Lower thoracic (ref) vs upper thoracic/lumbar (n = 101)	3.97 (1.67, 10.56)	0.002	0.61 (0.03, 3.96)	0.656
Lumbar (ref) vs thoracic (n = 63)	0.14 (0.05, 0.33)	<0.001	0.14 (0.01, 0.83)	0.071
Insurance		0.947		-
Private (n = 20)	Reference	-	-	-
Public (n = 173)	1.04 (0.23, 3.40)	-	-	-
Time from injury to admission				
Continuous, d	0.93 (0.85, 0.99)	0.093	0.93 (0.84, 1.00)	0.113
Operative		0.034		0.067
Nonoperative (n = 55)	Reference	-	Reference	-
Operative (n = 138)	3.83 (1.27, 16.61)	-	3.58 (1.02, 17.07)	-
Admission neurologic examination		<0.001		0.002
Complete: ASIA A (n = 113)	Reference	-	Reference	-
Incomplete: ASIA B–D (n = 80)	8.71 (3.38, 27.05)	-	5.74 (1.94, 18.00)	-
Operative patients, N = 138				
Age		0.299		-
Young, <30 y (n = 57)	Reference	-	-	-
Old, ≥30 y (n = 81)	1.63 (0.66, 4.27)	-	-	-
Sex		0.921		-
Female (n = 23)	Reference	-	-	-
Male (n = 115)	1.06 (0.35, 3.94)	-	-	-
Injury level				
Upper thoracic (ref) vs lower thoracic/lumbar (n = 20)	4.85 (0.93, 89.30)	0.133	-	-
Lower thoracic (ref) vs upper thoracic/lumbar (n = 71)	3.36 (1.34, 9.22)	0.012	0.47 (0.02, 2.89)	0.495
Lumbar (ref) vs thoracic (n = 47)	0.17 (0.06, 0.42)	<0.001	0.09 (0.00, 0.51)	0.027
Time from admission to operating room				
Continuous, d	1.01 (0.99, 1.03)	0.237	-	-

Abbreviation: ASIA, American Spinal Injury Association.

^aASIA E patients were excluded, and none got worse in this cohort; only patients with a discharge ASIA score were included.^bExcluded from the logistic regression model due to collinearity.

DISCUSSION

Injuries to the thoracic, TL, and lumbar spine are common in the trauma population, and patients who suffer from them have a life-changing event, especially in low-income countries. This study addressed the patterns of presentation, operative treatment, neurologic improvement, and mortality following TL spine trauma at a large East African referral facility. While 90.3% of all patients had a surgical indication, it is notable that 72.2% of patients managed nonoperatively had indications. One hundred sixty-seven patients underwent surgery at a median of 17 days after admission. Almost all patients underwent a PLF, with an average of 2.7 levels fused with 5.6 screws. Patients with intact injuries and a longer duration before admission were less likely to undergo surgery. Neurologic improvement rates were low at 11.1%, with the majority (89%) occurring in the surgical group. Furthermore, compared

to patients with lumbar injuries, patients in the surgical group with thoracic injuries had decreased odds of improvement. The cohort's mortality rate was low, at 1.2%. Overall, this study highlights the relatively low surgical rates, delayed timing of surgery, safe surgery with minimal mortality, and the potential for neurological improvement associated with surgical intervention in thoracic, TL, and lumbar spine trauma patients in low-resource settings.

Lack of Operative Treatment Overall

A key finding of this study was the low surgery rates. Among the patients managed without surgery, 72.2% had indications for surgery. Surgical procedures for traumatic spinal injuries are performed in several LMICs, and they remain relatively scarce and carry significant risks as evidenced by a study reporting increased complications and mortality

Table 7. Predictors of mortality among all patients ($N = 257$).

Variable	Univariable Logistic Regression	
	OR (95% CI)	P
Age		
Young, <30 y ($n = 91$)	Reference	0.940
Old, ≥ 30 y ($n = 166$)	1.10 (0.10, 23.81)	-
Sex		
Female ($n = 42$)	Reference	0.995
Male ($n = 215$)	1.20 (0.00, NA)	-
Injury level		
Upper thoracic ($n = 33$)	Reference	-
Lower thoracic ($n = 122$)	6.00 (0.00, NA)	0.997
Lumbar ($n = 102$)	1.00 (0.00, 3.00)	>0.999
Insurance		
Public	Reference	0.996
Private	1.15 (0.00, NA)	-
Time from injury to admission		
Continuous, d	0.90 (0.53, 1.07)	0.517
Operative status		
Nonoperative ($n = 90$)	Reference	0.281
Operative ($n = 167$)	0.27 (0.01, 2.80)	-
Admission neurologic examination		
Complete: ASIA B-E (n)	Reference	0.994
Incomplete: ASIA A (n)	6.11 (0.00, NA)	-
Length of stay, continuous, d	0.99 (0.93, 1.02)	0.806

Abbreviation: ASIA, American Spinal Injury Association.

Multivariable logistic regression analyses were not completed because no predictors met the threshold of $p < 0.10$ after univariable logistic regression analysis.

rates among patients who underwent surgery.²² Low surgery rates are not specific to spine trauma alone but are commonly observed across various surgical specialties in LMICs. A study demonstrated that only a disproportionately small percentage, approximately 6.3% globally,²³ of surgical procedures are performed in LMICs, despite the substantial burden of surgical conditions experienced in these regions.²⁴

Several barriers, including financial constraints, inadequate referral systems, and poor health care-seeking behavior, result in reduced surgery rates in LMICs.²⁵ Limited financial resources often impede access to surgery, necessary implants, surgical care, and comprehensive clinical management.²⁶ For instance, in a Nigerian study by Nwanko et al,²⁷ strut grafts and interspinous wiring were utilized to minimize costs, yet 43% of the remaining 68 patients with indications for surgery could not undergo operative treatment due to their inability to pay. Similarly, in this study, 87.5% of patients lacked health insurance and had to cover their medical expenses out-of-pocket, which may have influenced the decision to undergo surgery. Our group's initial study also highlighted that implant availability and economic factors such as insurance status significantly influence the decision to perform surgery and the timing of surgery.^{19,28}

Furthermore, the choice of construct size may have been affected by the ability to pay as short-segment

fixation was predominantly utilized, with an average fusion level of fewer than 3. While long-segment fixation does not necessarily offer substantial advantages over short-segment fixation, there are inherent risks associated with short-segment constructs when the upper and lower instrumented vertebrae involve the fractured levels or when constructs end at junctional levels.¹⁹ These risks could be effectively mitigated with improved access to implants.

Predictors of Surgery

Surgery is vital for managing spine trauma by restoring spinal anatomy, ensuring mechanical stability, and preserving or improving neurological function.⁹ Our research indicates that patients with intact injuries are less likely to undergo surgery than those with incomplete or complete injuries. This distinction arises from the fact that surgery is typically reserved for cases involving instability, deformity, or compression of neural structures that could lead to neurological deficits. Conversely, conservative management approaches such as brace or orthotic immobilization, pain management, and physical therapy are often sufficient for promoting healing and recovery in patients with intact injuries.¹³

Furthermore, our findings reveal that patients with a longer duration before seeking medical attention are less likely to undergo surgery. The delayed presentation can give rise to increased complications, including the development of pressure sores, chest infections, and other medical conditions. Additionally, the delayed admission may contribute to the natural fusion of the injured spine, reducing the necessity for surgical intervention.

It is important to emphasize that the decision regarding surgery for thoracic, TL, and lumbar spine trauma is complex and should be based on a comprehensive evaluation of the individual patient's clinical presentation, imaging findings, neurological status, and overall health. This process typically involves a multidisciplinary approach involving spine surgeons and other health care professionals. By considering these factors, the most appropriate treatment plan can be determined for each patient.

Neurological Improvement

Timely surgical intervention, particularly within the first 72 hours, significantly impacts the potential for neurological improvement in patients with thoracic, TL, and lumbar spine injury.²⁹ Surgery plays a crucial role by facilitating the removal of

retropulsion bone fragments, decompressing nerve roots, and providing structural support. When performed early, surgery enables early mobilization, reduces complications, and leads to shorter hospital stays and less time in intensive care units.

Our study noted a median time of 17 days from admission to surgery, which likely explains our cohort's relatively low rate of neurological improvement of 11.1% at discharge. Despite this delay, we found that surgery showed potential neurological improvement. Patients who underwent surgery had more than three times the likelihood of experiencing improvement than those who did not. Remarkably, a similar study conducted in India revealed that even with a mean interval of 24.45 days between injury and spine surgery, 51.5% of patients achieved an increase of at least 1 in their ASIA grade at the 1-year follow-up.³⁰ This highlights that there is still a significant chance of neurological improvement even after delayed surgery. These findings are intriguing as they underscore the potential for neurological improvement even in cases of delayed surgical intervention, often encountered in resource-limited settings. Consequently, they emphasize the critical role of surgical decompression in thoracic, TL, and lumbar spine trauma patients, irrespective of any delay in the surgical procedure.

In addition to surgery and timing, neurological improvement in thoracic, TL, and lumbar spine trauma is influenced by multiple factors, including injury severity (measured by admission ASIA grade) and the specific spinal cord region affected.³¹ A study focusing on neurologic improvement after thoracic, TL, and lumbar spine injuries revealed that patients with lumbar impairment had a significantly higher likelihood of improvement in ASIA levels (up to 90%) compared to those with thoracic and TL injuries (22.4% improvement).³² Their study also revealed that incomplete injuries (ASIA B–D) exhibited significantly higher rates of improvement (95.2% for ASIA D) compared to complete injuries (7.7% for ASIA A).

Our study identified incomplete injury (ASIA B–D) as the sole independent predictor of neurological improvement, with patients experiencing nearly a 6-fold increase in the likelihood of improvement compared to those with complete injuries. Furthermore, among patients who underwent surgery, individuals with thoracic injuries had a lower chance of improvement (9%) compared to those with lumbar injuries. This discrepancy can be attributed to

several factors. The lower rates of improvement in the thoracic spine can be linked to the prevalence of complete neurological deficits typically associated with thoracic fractures.³³ A smaller canal diameter characterizes the thoracic region and is often implicated in high-energy mechanism injuries due to its inherent rigid structure, which may predispose it to complete injuries.^{13,34} In contrast, the lumbar region benefits from a higher proportion of lower-to-upper motor neurons in the distal spinal cord and the potential for “root escape.”³⁵

Mortality

Mortality is a common complication following spine trauma, and it has consistently been observed that mortality rates are significantly higher in cervical injuries compared to thoracic, TL, and lumbar injuries.²⁸ In northeast Tanzania, rural India, and Nigeria, the reported mortality rates for cervical trauma were 27.2%,³⁶ 30%,³⁷ and 72%,³⁸ respectively. Conversely, mortality rates following thoracic, TL, and lumbar injuries in the same regions were comparatively lower, with 17.9% in northeast Tanzania,³⁶ 4.3% in rural India,³⁷ and 28% in Nigeria.³⁸ The higher mortality rates associated with cervical injuries can be attributed to the involvement of upper segments of the spinal cord responsible for vital functions like respiration.³⁹ Additionally, cervical injuries are more likely to result in complete injuries, which are known to be associated with higher complications.

This study examined mortality rates following thoracic, TL, and lumbar spine injuries, which were 1.2%. This finding aligns with the existing literature, as a meta-analysis reported in-hospital mortality rates ranging from 0% to 10% for thoracic, TL, and lumbar spine injuries.⁴⁰ Similarly, a recent study conducted in Cameroon described a mortality rate of 5.7%.⁴¹ Although our regression analysis did not reveal any predictors of mortality, there was a noticeable trend suggesting a reduction in mortality among patients who underwent surgical intervention. This trend can be attributed to several factors, including early mobilization facilitated by surgery.⁵ Moreover, advancements in surgical skills, anesthesia techniques, and postoperative nursing care have significantly contributed to the improved safety and success of surgical procedures in treating thoracic, TL, and lumbar spine injuries. These findings underscore the importance of surgical management in achieving favorable outcomes and reducing

mortality rates in the context of thoracic, TL, and lumbar spine injuries in Africa.

Areas of Improvement

The management of thoracic, TL, and lumbar spine injuries in Tanzania has experienced significant advancements thanks to international collaboration and partnerships, including the collaboration between the Department of Neurosurgery at MOI and the Department of Neurosurgery at Weill Cornell Medical College.⁴²⁻⁴⁴ These collaborative efforts, training programs, and accumulated experiences have been crucial in improving TSI management. However, despite these positive developments, the outcomes of TSI patients in Tanzania still fall behind those observed in HICs.² It is worth noting that in our series, road traffic accidents account for nearly half of the cases. This underscores the urgent need for targeted interventions aimed at improving road safety.

While prevention should be a key focus, it is also essential to direct attention toward other areas of improvement. One such area is the need to establish additional spine trauma centers. A previous study by our group revealed that patients, on average, have to travel a distance of 278 km to access proper care.²⁸ This significant travel distance delays receiving necessary surgical interventions, ultimately impacting patient outcomes. This study's median time from injury to admission was 3 days, highlighting the urgent need to address this delay. Furthermore, there is an overwhelming number of trauma patients in Tanzania. According to estimates,⁴⁵ approximately 5,227 trauma patients are admitted daily to only 105 district and regional hospitals designated for trauma cases. Increasing the number of spine centers in the region can effectively reduce the time gap between trauma and timely medical or surgical intervention. However, it is crucial to recognize that establishing, accrediting, and maintaining such centers can be resource-intensive and costly, despite their potential cost-effectiveness.⁴⁶

There is also an urgent need to improve surgical skills. While the surgical expertise at MOI is commendable, there is room for further enhancement by adopting new approaches, such as anterior or lateral approaches. One potential avenue for improvement is to allow local surgeons to participate in short-term spine fellowship programs, which would facilitate acquiring new skills and techniques.^{47,48}

Finally, there is a need to implement the consistent use of a region-specific spine trauma protocol. Standardized management protocols in health care have demonstrated benefits, including increased consistency, reduced heterogeneity in patient care, prevention of harm, improved adherence to evidence-based recommendations, reduced cognitive strain, and enhanced communication among health care providers.⁴⁹ Currently, there is no consistent use of a trauma protocol for this patient group in the region. Implementing a region-specific protocol for trauma patients is expected to yield better outcomes. Our objective moving forward is to ensure the consistent use of a region-specific trauma protocol.

By focusing on these areas of improvement, including preventive measures, establishing additional trauma centers, addressing discrepancies in fusion techniques, enhancing surgical skills, and consistent use of a region-specific trauma protocol, Tanzania can make significant strides in the management of thoracic, TL, and lumbar spine injuries, ultimately improving patient outcomes and narrowing the gap between local practices and international standards.

Limitations

This study has certain limitations. First, there are missing data in the dataset, which were handled using pairwise deletion, although it may not be the optimal method. However, since the missing data were <5%, it is unlikely to affect the results significantly. Second, the study relied on data from a single institution, limiting the generalizability of the findings. Nevertheless, the hospital is a prominent spine trauma referral center with a diverse patient population, as indicated by patients traveling an average distance of approximately 280 km. Therefore, the results may apply to other emerging countries with similar demographics. Third, neurologic evaluations were only conducted at the time of discharge, preventing assessment of subsequent improvement or decline. Fourth, the data were retrospectively analyzed despite the cohort derived from a prospectively maintained spine database. Fifth, our data collection is limited to pressure sores, omitting other nonspine-related complications like pneumonia. This oversight could be significant as these complications often increase with nonoperative or delayed operative treatments. Future studies will seek to broaden data collection to encompass a broader range of nonspine-related complications. In

summary, while the lack of follow-up data hampers our analysis, it also underscores the challenges of conducting research and performing surgeries in low-resource settings. Nonetheless, we hope that the scientific conclusions can enhance the care provided to spinal trauma patients in Tanzania.

CONCLUSION

This study has illuminated key aspects of managing thoracic, TL, and lumbar spine trauma patients in a resource-constrained setting. Approximately two-thirds of patients with thoracic, TL, and lumbar spine trauma underwent surgical decompression and stabilization. The median duration from admission to surgery was found to be 17 days. Notably, patients who had no neurological deficits and those with a longer time interval between injury and admission had lower rates of undergoing surgery. However, it was observed that surgery was associated with improvements in neurological function. Surgical intervention has proven crucial, particularly for patients with incomplete injuries, offering potential neurological improvement even after delayed surgery.

To further enhance patient care and outcomes, addressing road safety, establishing additional spine trauma centers, improving surgical skills, and implementing a region-specific trauma protocol are essential steps. These measures can help bridge the gap between local practices and international standards in managing spine trauma patients in Tanzania and similar resource-limited contexts. Despite its study limitations, our study's findings contribute to the ongoing efforts to enhance spinal trauma patient care in such settings.

ACKNOWLEDGMENTS

We thank the interdisciplinary team, including nurses, residents, and fellows, who cared for these patients.

REFERENCES

1. Magogo J, Lazaro A, Mango M, et al. Operative treatment of traumatic spinal injuries in Tanzania: surgical management, neurologic outcomes, and time to surgery. *Global Spine J.* 2021;11(1):89–98. doi:10.1177/2192568219894956
2. Chanbour H, Chen JW, Ehtesham SA, et al. Time to surgery in spinal trauma: a meta-analysis of the world's literature comparing high-income countries to low-middle income countries. *World Neurosurg.* 2022;167:e268–e282. doi:10.1016/j.wneu.2022.07.140
3. Kumar R, Lim J, Mekary RA, et al. Traumatic spinal injury: global epidemiology and worldwide volume. *World Neurosurg.* 2018;113:e345–e363. doi:10.1016/j.wneu.2018.02.033
4. Weiser TG, Regenbogen SE, Thompson KD, et al. An estimation of the global volume of surgery: a modelling strategy based on available data. *Lancet.* 2008;372(9633):139–144. doi:10.1016/S0140-6736(08)60878-8
5. Ahuja CS, Badhiwala JH, Fehlings MG. Time is spine: the importance of early intervention for traumatic spinal cord injury. *Spinal Cord.* 2020;58(9):1037–1039. doi:10.1038/s41393-020-0477-8
6. Fehlings MG, Vaccaro A, Wilson JR, et al. Early versus delayed decompression for traumatic cervical spinal cord injury: results of the surgical timing in acute spinal cord injury study (STASCIS). *PLOS ONE.* 2012;7(2):e32037. doi:10.1371/journal.pone.0032037
7. Lessing NL, Mwesige S, Lazaro A, et al. Pressure ulcers after traumatic spinal injury in East Africa: risk factors, illustrative case, and low-cost protocol for prevention and treatment. *Spinal Cord Ser Cases.* 2020;6(1):48. doi:10.1038/s41394-020-0294-5
8. Khurana B, Sheehan SE, Sodickson A, Bono CM, Harris MB. Traumatic thoracolumbar spine injuries: what the spine surgeon wants to know. *Radiographics.* 2013;33(7):2031–2046. doi:10.1148/rg.337135018
9. Rajasekaran S, Kanna RM, Shetty AP. Management of thoracolumbar spine trauma: an overview. *Indian J Orthop.* 2015;49(1):72–82. doi:10.4103/0019-5413.143914
10. Gertzbein SD. Scoliosis research society. multicenter spine fracture study. *Spine (Phila Pa 1976).* 1992;17(5):528–540. doi:10.1097/00007632-199205000-00010
11. Gertzbein SD, Khoury D, Bullington A, St John TA, Larson AI. Thoracic and lumbar fractures associated with skiing and snowboarding injuries according to the AO comprehensive classification. *Am J Sports Med.* 2012;40(8):1750–1754. doi:10.1177/0363546512449814
12. Benson DR, Burkus JK, Montesano PX, Sutherland TB, McLain RF. Unstable thoracolumbar and lumbar burst fractures treated with the AO fixateur interne. *J Spinal Disord.* 1992;5(3):335–343. doi:10.1097/00002517-199209000-00012
13. Wood KB, Li W, Lebl DR, Ploumis A. Management of thoracolumbar spine fractures. *Spine J.* 2014;14(1):145–164. doi:10.1016/j.spinee.2012.10.041
14. Yacoub AR, Joaquim AF, Ghizoni E, Tedeschi H, Patel AA. Evaluation of the safety and reliability of the newly-proposed AO spine injury classification system. *J Spinal Cord Med.* 2017;40(1):70–75. doi:10.1179/2045772315Y.0000000042
15. Knop C, Blauth M, Bühren V, et al. Surgical treatment of injuries of the thoracolumbar transition. 1: epidemiology. *Unfallchirurg.* 1999;102(12):924–935. doi:10.1007/s001130050507
16. Vaccaro AR, Kim DH, Brodke DS, et al. Diagnosis and management of thoracolumbar spine fractures. *Instr Course Lect.* 2004;53:359–373.
17. Choi JH, Park PJ, Din V, Sam N, Iv V, Park KB. Epidemiology and clinical management of traumatic spine injuries at a major government hospital in Cambodia. *Asian Spine J.* 2017;11(6):908–916. doi:10.4184/asj.2017.11.6.908
18. Schnake KJ, Schroeder GD, Vaccaro AR, Oner C. Aospine classification systems (subaxial, thoracolumbar). *J Orthop Trauma.* 2017;31 Suppl 4:S14–S23. doi:10.1097/BOT.0000000000000947
19. Magogo J, Lazaro A, Mango M, et al. Operative treatment of traumatic spinal injuries in Tanzania: surgical

management, neurologic outcomes, and time to surgery. *Global Spine J.* 2021;11(1):89–98. doi:10.1177/2192568219894956

20. Kirshblum SC, Waring W, Biering-Sorensen F, et al. Reference for the 2011 revision of the international standards for neurological classification of spinal cord injury. *J Spinal Cord Med.* 2011;34(6):547–554. doi:10.1179/107902611X13186000420242

21. Lessing NL, Lazaro A, Zuckerman SL, et al. Nonoperative treatment of traumatic spinal injuries in Tanzania: who is not undergoing surgery and why?. *Spinal Cord.* 2020;58(11):1197–1205. doi:10.1038/s41393-020-0474-y

22. Aleem IS, DeMarco D, Drew B, et al. The burden of spine fractures in India: a prospective multicenter study. *Global Spine J.* 2017;7(4):325–333. doi:10.1177/2192568217694362

23. Greenberg SLM, Ng-Kamstra JS, Ameh EA, Ozgediz DE, Poenaru D, Bickler SW. An investment in knowledge: research in global pediatric surgery for the 21st century. *Semin Pediatr Surg.* 2016;25(1):51–60. doi:10.1053/j.sempedsurg.2015.09.009

24. Shrimel MG, Bickler SW, Alkire BC, Mock C. Global burden of surgical disease: an estimation from the provider perspective. *Lancet Glob Health.* 2015;3 Suppl 2:S8–9. doi:10.1016/S2214-109X(14)70384-5

25. Ikwuegbuanyi CA, Umutooni A, Atabe Ngwene NN, et al. Public awareness, knowledge of availability, and willingness to use neurosurgical care services in sub-Saharan Africa: a cross-sectional study. *PLoS One.* 2022;17(3):e0264955. doi:10.1371/journal.pone.0264955

26. Lessing NL, Zuckerman SL, Lazaro A, et al. Cost-effectiveness of operating on traumatic spinal injuries in low-middle income countries: a preliminary report from a major East African referral center. *Global Spine J.* 2022;12(1):15–23. doi:10.1177/2192568220944888

27. Nwankwo OE, Uche EO. Epidemiological and treatment profiles of spinal cord injury in Southeast Nigeria. *Spinal Cord.* 2013;51(6):448–452. doi:10.1038/sc.2013.10

28. Leiding A, Kim EE, Navarro-Ramirez R, et al. Spinal trauma in Tanzania: current management and outcomes. *J Neurosurg Spine.* 2019;31(1):103–111. doi:10.3171/2018.12.SPINE18635

29. Qadir I, Riew KD, Alam SR, Akram R, Waqas M, Aziz A. Timing of surgery in thoracolumbar spine injury: impact on neurological outcome. *Global Spine J.* 2020;10(7):826–831. doi:10.1177/2192568219876258

30. Rathod TN, Sathe AH, Marathe NA, et al. Better late than never: clinical outcomes of delayed fixation in thoracolumbar spinal trauma. *Eur Spine J.* 2021;30(10):3081–3088. doi:10.1007/s00586-021-06804-5

31. Khorasanizadeh M, Yousefifard M, Eskian M, et al. Neurological recovery following traumatic spinal cord injury: a systematic review and meta-analysis. *J Neurosurg Spine.* 2019;30(5):1–17. doi:10.3171/2018.10.SPINE18802

32. Harrop JS, Naroji S, Maltenfort MG, et al. Neurologic improvement after thoracic, thoracolumbar, and lumbar spinal cord (conus medullaris) injuries. *Spine (Phila Pa 1976).* 2011;36(1):21–25. doi:10.1097/BRS.0b013e3181fd6b36

33. Wang H, Zhang Y, Xiang Q, et al. Epidemiology of traumatic spinal fractures: experience from medical university-affiliated hospitals in Chongqing. *J Neurosurg Spine.* 2012;17(5):459–468. doi:10.3171/2012.8.SPINE111003

34. el-Khoury GY, Whitten CG. Trauma to the upper thoracic spine: anatomy, biomechanics, and unique imaging features. *AJR Am J Roentgenol.* 1993;160(1):95–102. doi:10.2214/ajr.160.1.8416656

35. Rahimi-Movaghar V, Vaccaro AR, Mohammadi M. Efficacy of surgical decompression in regard to motor recovery in the setting of conus medullaris injury. *J Spinal Cord Med.* 2006;29(1):32–38. doi:10.1080/10790268.2006.11753854

36. Moshi H, Sundelin G, Sahlen KG, Sörlin A. Traumatic spinal cord injury in the North-East Tanzania - describing incidence, etiology and clinical outcomes retrospectively. *Glob Health Action.* 2017;10(1):1355604. doi:10.1080/16549716.2017.1355604

37. Chacko V, Joseph B, Mohanty SP, Jacob T. Management of spinal cord injury in a general hospital in rural India. *Paraplegia.* 1986;24(5):330–335. doi:10.1038/sc.1986.48

38. Obalum DC, Giwa SO, Adekoya-Cole TO, Enweluzo GO. Profile of spinal injuries in Lagos, Nigeria. *Spinal Cord.* 2009;47(2):134–137. doi:10.1038/sc.2008.93

39. Zuckerman SL, Haghdel A, Lessing NL, et al. Cervical spine trauma in East Africa: presentation, treatment, and mortality. *Int J Spine Surg.* 2021;15(5):879–889. doi:10.14444/8113

40. Azarhomayoun A, Aghasi M, Mousavi N, et al. Mortality rate and predicting factors of traumatic thoracolumbar spinal cord injury; a systematic review and meta-analysis. *Bull Emerg Trauma.* 2018;6(3):181–194. doi:10.29252/beat-060301

41. Shu PC, Motah M, Massi DG, Ngunyi YL, Budzi NM, Mefire AC. Thoracolumbar spine injury in cameroon: etiology, management, and outcome. *BMC Musculoskelet Disord.* 2023;24(1):386. doi:10.1186/s12891-023-06481-z

42. Mangat HS, Schöller K, Budohoski KP, et al. Neurosurgery in East Africa: foundations. *World Neurosurg.* 2018;113:S1878-8750(18)30129-3:411–424. doi:10.1016/j.wneu.2018.01.086

43. Budohoski KP, Ngerageza JG, Austard B, et al. Neurosurgery in East Africa: innovations. *World Neurosurg.* 2018;113:436–452. doi:10.1016/j.wneu.2018.01.085

44. Santos MM, Qureshi MM, Budohoski KP, et al. The growth of neurosurgery in East Africa: challenges. *World Neurosurg.* 2018;113:425–435. doi:10.1016/j.wneu.2018.01.084

45. Sawe HR, Mfinanga JA, Mbaya KR, et al. Trauma burden in Tanzania: a one-day survey of all district and regional public hospitals. *BMC Emerg Med.* 2017;17(1):30. doi:10.1186/s12873-017-0141-6

46. MacKenzie EJ, Weir S, Rivara FP, et al. The value of trauma center care. *J Trauma.* 2010;69(1):1–10. doi:10.1097/TA.0b013e3181e03a21

47. Kahamba JF, Assey AB, Dempsey RJ, Qureshi MM, Härtl R. The second African federation of neurological surgeons course in the east, central, and southern Africa region held in Dar es Salaam. *World Neurosurg.* 2013;80(3–4):255–259. doi:10.1016/j.wneu.2011.07.021

48. Waterkeyn F, Woodfield J, Massawe SL, et al. The effect of the Dar es Salaam neurosurgery training course on self-reported neurosurgical knowledge and confidence. *Brain Spine.* 2023;3:101727. doi:10.1016/j.bas.2023.101727

49. English SW, Turgeon AF, Owen E, Doucette S, Pagliarello G, McIntyre L. Protocol management of severe traumatic brain injury in intensive care units: a systematic review. *Neurocrit Care.* 2013;18(1):131–142. doi:10.1007/s12028-012-9748-3

Funding: The authors received no financial support for the research, authorship, and/or publication of this article. While this research did not receive specific funding, some implants used in the management of patients

in this study were donated by DePuy Synthes. This support did not influence any aspect of the study.

Disclosures: Roger Hartl reports royalties from Zimmer Biomet, consulting fees from DePuy Synthes and Brainlab, and serving as an advisor with RealSpine and 3D Bio. The remaining authors report no disclosures.

Ethical Considerations: For the quality improvement database utilized in this study, participants were identified through daily reviews of admitted patients. Routine clinical data were entered into the quality improvement database by clinicians caring for the patients. The ethical review committees of the Muhimbili University of Health and Allied Sciences (Dar es Salaam, Tanzania) and Weill Cornell Medicine (New York, USA) reviewed the database (20-01021336).

It was determined that further institutional board review and patient consent were not required for entry into the quality improvement database or anonymous analysis of the database. For the images used in this study, written informed consent was obtained from the patient before submission.

Corresponding Author: Roger Härtl, Weill Cornell Medicine Center for Comprehensive Spine Care, 240 E 59th St, 2nd Floor, New York, NY 10022, USA; roh9005@med.cornell.edu

Published 15 March 2024

This manuscript is generously published free of charge by ISASS, the International Society for the Advancement of Spine Surgery. Copyright © 2024 ISASS. To see more or order reprints or permissions, see <http://ijssurgery.com>.