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Traumatic Spinal Cord Injury: Retrospective Evaluation of Epidemiological and Hematological Profiles

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ABSTRACT

Background: Traumatic spinal cord injury (TSCI) represents a major public health concern, with significant long-term consequences for patients' physical, psychological, and social functioning. Understanding epidemiological patterns and identifying reliable hematological markers associated with functional outcomes may help in optimizing clinical management.

Methods: Medical records of patients with TSCI admitted to Xuanwu Hospital, Capital Medical University, between January 2015 and December 2021 were retrospectively reviewed. A total of 129 cases were included for epidemiological analysis. For hematological profiling, 106 patients with cervical TSCI who were admitted within six months of injury and had complete laboratory data were analyzed. Epidemiological variables included demographic details, etiology, injury level, treatment, time to hospital, and discharge destination. Hematological variables assessed at admission included white blood cell count, neutrophil and lymphocyte counts and percentages, hemoglobin (Hb), platelets (PLT), albumin (Alb), glucose, and fibrinogen. Functional outcome was assessed using the Barthel Index (BI) at admission and discharge. Statistical analyses included independent-samples t-tests, Mann–Whitney U-tests, binary logistic regression, and ROC curve analysis.

Results: The mean age of patients was 56.3 ± 13.3 years, with the 46–60-year group being the most affected (49.6%). The male-to-female ratio was 2.5:1. Low fall (50.4%) was the leading cause of injury, followed by transport-related accidents (25.6%) and falls from height (13.2%). The majority of injuries involved the cervical spine (86.0%), with C5 being the most frequent level. Surgical treatment was performed in 91.5% of cases. At discharge, only 27.2% of patients had received rehabilitation therapy. Hematological analysis revealed that patients with increased BI scores had significantly higher admission levels of Hb (137.7 ± 16.8 g/L vs. 125.9 ± 19.6 g/L, p=0.008) and Alb (37.3 ± 4.7 g/L vs. 34.1 ± 5.3 g/L, p=0.001). Logistic regression identified Alb as an independent predictor of functional improvement (OR=1.121, p=0.039). ROC analysis determined a cut-off Alb level of 33.16 g/L (AUC=0.669).

Conclusions: TSCI in Turkey predominantly affects middle-aged men, with low falls being the major etiology and cervical spine injuries the most common. Admission albumin level was independently associated with functional improvement during hospitalization, suggesting its potential as a readily available prognostic marker. Larger, prospective, and multicentre studies are warranted to validate these findings.

INTRODUCTION

Traumatic spinal cord injury (TSCI) is a life-changing event that frequently results in long-term disability, loss of independence, and socioeconomic burden. Long et al. (2021), Chen J et al. (2021). Despite improvements in trauma care, effective curative treatments remain limited, making prevention strategies essential. Feng H et al. (2021), Chhabra H et al. (2012). Epidemiological data are crucial for shaping public health initiatives, guiding resource allocation, and designing injury-prevention programs.

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Several high-income countries maintain national registries for spinal cord injury, but such systems are limited in middle-income regions like Turkey. Jogia T et al. (2021), Biering-Sorensen F et al. (2017). Considering that epidemiological patterns vary considerably across geographical areas due to cultural, social, and environmental factors, country-specific studies are needed to tailor effective preventive measures.

Prognosis after TSCI is typically based on neurological examinations, which are often impractical in acute settings. Liu H et al. (2021), Feng H et al. (2013) Easily accessible biomarkers from routine blood samples may serve as surrogate predictors for recovery. Albumin (Alb) and hemoglobin (Hb), in particular, have been linked to outcomes in neurological disorders and may have prognostic value in TSCI.

Hacettepe University Hospital, located in Ankara, Turkey, is a tertiary referral center for neurosurgery and trauma care. Wang H F et al. (2013), Liu Jet al. (2020), Mirzaeva L et al. (2019) This study aimed to analyze the epidemiological features and hematological predictors of functional recovery in TSCI patients admitted over a seven-year period.

MATERIALS AND METHODS

Study Design and Population

We retrospectively reviewed the medical records of all patients with TSCI admitted to Xuanwu Hospital, Capital Medical University, from January 2015 to December 2021. Kudo D et al. (2019), Rodriguez-Meza M V et al. (2016), Johansson E et al. (2021) Data collection was performed in 2022 from 129 complete case sheets.

Inclusion criteria: Patients diagnosed with TSCI, defined as impairment of spinal cord or cauda equina function due to an external force.

Exclusion criteria

1. Non-traumatic spinal cord injury.

2. Incomplete or uncertain medical records.

For hematological analysis, patients with non-cervical TSCI or with hospital admission more than six months post-injury were excluded. Moshi H et al. (2017), Sabre L et al. (2012), Agarwal P et al. (2007) This resulted in 106 eligible patients.

Data Collection

Epidemiological variables included age, gender, marital status, cause of injury, time from injury to admission, injury level, treatment modality, hospital stay, and discharge destination. Gur A et al. (2005), Dryden DM et al. (2003) Functional status was measured by the Barthel Index (BI) at admission and discharge.

Hematological parameters at admission included: white blood cell count (WBC), neutrophil count (N), neutrophil percentage (N%), lymphocyte count (L), lymphocyte percentage (L%), hemoglobin (Hb), platelets (PLT), albumin (Alb), glucose, and fibrinogen. Dunham K A et al. (2010)- Korhonen N et al. (2014).

Statistical Analysis

Data were entered into Microsoft Excel and cross-verified by two researchers. Li J et al. (2011), Prasad K et al. (2018), Dos Santos Barros V et al. (2022) Statistical analysis was conducted using IBM SPSS version 26.0. Epidemiological variables were expressed as frequencies and percentages. Hematological variables were reported as mean ± standard deviation (SD).

Patients were divided into two groups:

• Increased BI group: discharge BI > admission BI.

• Non-increased BI group: discharge BI ≤ admission BI.

Independent-samples t-tests and Mann–Whitney U-tests were used for group comparisons. Zhang J L et al. (2015) Variables with $p \leq 0.1$ were entered into binary logistic regression to identify independent predictors. Vo AK et al. (2021), Tong B et al. (2018) Receiver operating characteristic (ROC) analysis was used to determine predictive cut-offs. A p-value < 0.05 was considered statistically significant.

RESULTS

Demographic and Epidemiological Characteristics

A total of 129 patients with TSCI were included. The mean age was 56.3 ± 13.3 years (range 10–93). The age group most affected was 46–60 years (n=64, 49.6%), followed by 61–75 years (n=36, 27.9%). Only two patients (1.6%) were under 30 years. Males predominated (n=92, 71.3%), with a male-to-female ratio of 2.5:1. (Table 1 and Figure 1)

Figure 1: The age with gender comparison.

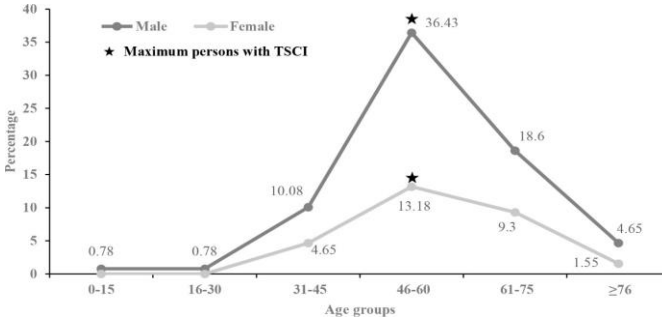


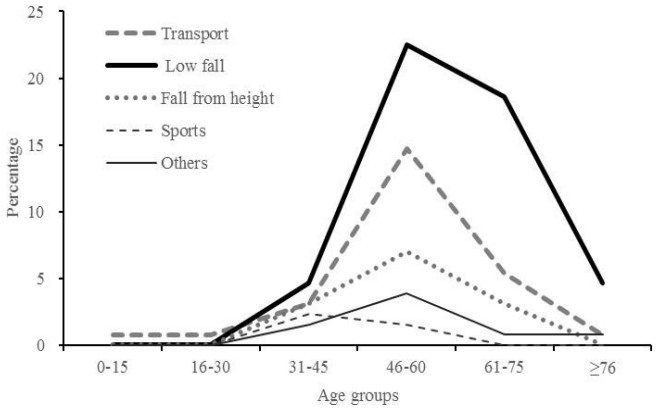
Table 1: Demographic and epidemiological characteristics of patients with TSCI (n = 129)

Variable	n (%) or mean ± SD
Age (years)	56.3 ± 13.3 (range 10–93)
Age group	
– ≤30	2 (1.6%)
– 31–45	11 (8.5%)
– 46–60	64 (49.6%)
– 61–75	36 (27.9%)
– ≥76	16 (12.4%)
Sex	
– Male	92 (71.3%)
– Female	37 (28.7%)
Marital status	
– Married	122 (94.6%)
– Unmarried	4 (3.1%)
– Widowed/divorced	3 (2.3%)
Etiology	
– Low fall	65 (50.4%)
– Transport accident	33 (25.6%)
– Fall from height	17 (13.2%)
– Sports-related	5 (3.9%)
– Other	9 (7.0%)

Marital status analysis showed that the vast majority of patients were married (94.6%), with only a small proportion unmarried (3.1%) or widowed/divorced (2.3%).

Regarding etiology, low falls accounted for more than half of cases (n=65, 50.4%), followed by transport-related injuries (n=33, 25.6%) and falls from height (n=17, 13.2%). Sports-related accidents (3.9%) and other causes (7.0%) were less common. Low falls were particularly prominent among patients over 45 years of age.

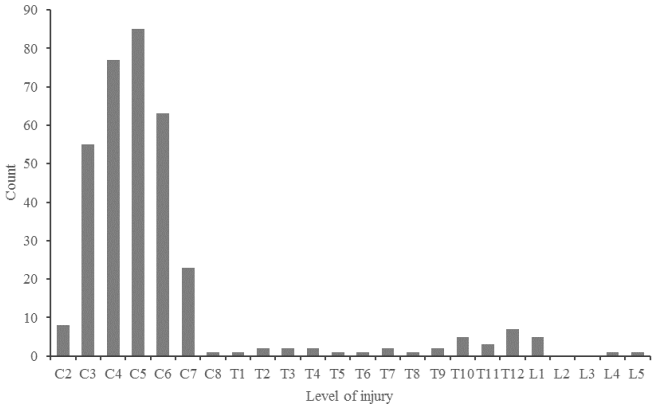
Figure 2: Distribution line chart for etiology according to age



Cervical injuries predominated, affecting 86.0% (n=111) of patients, with the highest incidence at C5, followed by C4. Thoracic (8.5%), lumbar (2.3%), and cervico-thoracic (0.8%) injuries were less frequent. (Figure 2)

In terms of healthcare access, only 4.7% of patients were admitted within 24 hours post-injury, while most arrived between 1–2 days (32.6%) or 8–30 days (24.8%) after trauma. A smaller group presented later than 3 months (14.7%). The median hospital stay was 10 days (range 1–34).

Figure 3: Distribution histogram of the injury level of TSCI.



Treatment was predominantly surgical (91.5%), with only 8.5% managed conservatively. At discharge, 13.2% were transferred to the hospital's rehabilitation department, 14.0% to rehabilitation hospitals, and 48.8% returned home without rehabilitation. In 24.0% of cases, the post-acute destination was unclear. (Figure 3 & Table 1).

Table 2: Injury profile, healthcare access, and treatment

Variable	n (%)
Injury level	
– Cervical	111 (86.0%)
– Thoracic	11 (8.5%)
– Lumbar	3 (2.3%)
– Cervico-thoracic	1 (0.8%)
– Multiple levels	3 (2.3%)
Time from injury to admission	
– ≤24 hours	6 (4.7%)
– 1–2 days	42 (32.6%)
– 3–7 days	30 (23.3%)
– 8–30 days	32 (24.8%)
– 1–3 months	10 (7.8%)
– >3 months	19 (14.7%)
Hospital stays (days)	Median 10 (range 1–34)
Treatment type	
– Surgical	118 (91.5%)
– Conservative	11 (8.5%)
Post-discharge destination	
– Rehab (in-hospital)	17 (13.2%)
– Rehab hospital	18 (14.0%)
– Home without rehab	63 (48.8%)
– Unknown	31 (24.0%)

Comparative analysis revealed:

- Hemoglobin (Hb): significantly higher in the improved group (137.7 ± 16.8 g/L) compared with the non-improved group (125.9 ± 19.6 g/L; p=0.008).
- Albumin (Alb): significantly higher in the improved group (37.3 ± 4.7 g/L vs. 34.1 ± 5.3 g/L; p=0.001).
- Other parameters (WBC, N, L, PLT, glucose, fibrinogen) showed no significant differences (p>0.05).

Hematological Parameters and Functional Outcomes

Of the 106 cervical TSCI patients with complete hematological and BI data, 69 (65.1%) demonstrated improvement in BI scores during hospitalization, while 37 (34.9%) did not.

Figure 4: Receiver operation characteristics (ROC) curve showing relationship between Alb and the altered BI scores. AUC=0.669.

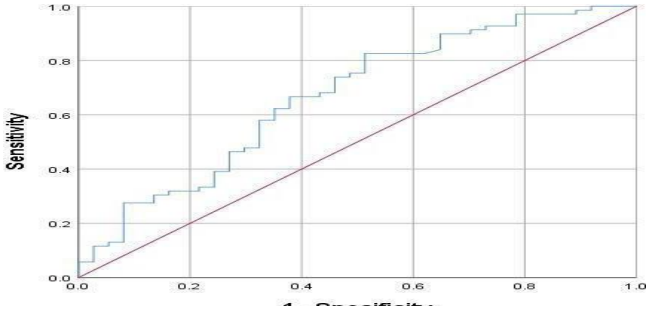


Table 3: Hematological parameters and functional improvement in cervical TSCI (n = 106)

Parameter	Improved (n=69)	Not Improved (n=37)	p-value
Hemoglobin (g/L)	137.7 ± 16.8	125.9 ± 19.6	0.008
Albumin (g/L)	37.3 ± 4.7	34.1 ± 5.3	0.001
WBC ($\times 10^9$/L)	7.6 ± 2.8	7.2 ± 2.5	0.52
Neutrophils ($\times 10^9$/L)	5.0 ± 2.1	4.8 ± 2.0	0.63
Lymphocytes ($\times 10^9$/L)	1.8 ± 0.7	1.7 ± 0.6	0.48
Platelets ($\times 10^9$/L)	221.3 ± 65.1	214.8 ± 61.2	0.62
Glucose (mmol/L)	6.1 ± 1.2	6.4 ± 1.4	0.29
Fibrinogen (g/L)	3.3 ± 0.7	3.5 ± 0.8	0.19

Binary logistic regression identified Alb as an independent predictor of functional improvement (OR=1.121, 95% CI 1.006–1.251, p=0.039). Hb showed a trend toward significance (p=0.10).

ROC analysis confirmed the predictive ability of Alb, with an AUC of 0.669. The Youden index identified a cut-off value of 33.16 g/L, above which patients were more likely to demonstrate improved BI scores at discharge.

DISCUSSION

This retrospective study provides important insights into the epidemiology and hematological correlates of TSCI in Beijing. Several key findings emerge.

First, the epidemiological profile indicates that TSCI in this cohort primarily affects middle-aged to elderly individuals, with a mean age of 56 years and nearly half of cases between 46–60 years. This contrasts with earlier studies in Beijing reporting a mean age of around 39 years, likely reflecting institutional differences and the growing burden of aging-related injuries in China. The male predominance (2.5:1) aligns with international data, underscoring the greater exposure of men to occupational and activity-related risks.

Second, low falls have surpassed transport accidents as the leading cause of TSCI, accounting for over half of all injuries. This is noteworthy because transport-related trauma has historically been dominant in many regions, particularly in high-income countries. The shift toward low falls likely reflects the demographic structure of Beijing, where rapid population aging increases vulnerability to minor falls that disproportionately cause cervical injuries. Preventive strategies should therefore emphasize fall prevention in the elderly alongside ongoing road safety efforts.

Third, the cervical region was the most frequently affected, with C5 being the single most common level of injury. This mirrors findings from both Chinese and international cohorts, particularly in older patients, where low-energy trauma tends to compromise cervical stability. The predominance of cervical TSCI has critical implications, as these injuries are typically associated with greater morbidity, functional dependency, and long-term care needs.

Fourth, while the majority of patients underwent surgery, rehabilitation utilization remained limited (27.2%). This is higher than older reports from Beijing but still falls short of optimal practice. Given the well-documented benefits of rehabilitation in maximizing recovery and reintegration, policies to improve post-acute rehabilitation access and adherence are urgently needed.

Finally, the hematological findings reveal a potentially important role of serum albumin as a prognostic marker. Higher Alb at admission was independently associated with functional improvement during hospitalization. The identified cut-off of 33.16 g/L offers a practical threshold for clinicians. Hypoalbuminemia likely reflects poor nutritional reserves, systemic inflammation, or concurrent illness, all of which may compromise recovery. While Hb was also associated with better outcomes, it did not remain significant in multivariate analysis.

Our results are consistent with prior studies linking hypoalbuminemia to poorer neurological recovery and higher complication rates in SCI. Albumin is a routinely available and inexpensive biomarker, making it a promising candidate for integration into clinical prognostic models. However, the moderate AUC (0.669) suggests it should be considered as part of a multifactorial assessment rather than a standalone predictor.

LIMITATIONS

This study has several limitations. First, it is a single-

center retrospective analysis, which may not fully capture the broader epidemiological profile of TSCI across China or other regions. The hospital setting also introduces selection bias, as it mainly receives patients with moderate to severe injuries who undergo surgical management, limiting generalizability to milder or conservatively treated cases.

Second, although we analyzed hematological parameters, we did not account for long-term follow-up outcomes. Functional improvement was assessed only during the hospital stay, which may underestimate or overestimate eventual recovery. Furthermore, important confounders such as nutritional interventions, rehabilitation intensity, and comorbidities were not systematically documented.

Finally, our sample size, though substantial, remains modest for detecting small effect sizes in multivariable models. Future multi-center studies with standardized outcome measures would help confirm and expand upon these findings.

FUTURE DIRECTIONS

The results of this study have several implications for both China and countries such as Turkey, where demographic trends and healthcare structures are similar. Turkey is also experiencing a rapidly aging population, with falls emerging as an increasingly important cause of injury. Future work should therefore prioritize:

1. Multicenter, prospective registries in both China and Turkey to capture real-world TSCI data, enabling cross-country comparisons of incidence, etiology, and outcomes.

2. Nutritional optimization and albumin monitoring as part of acute and subacute TSCI care. Interventional studies are needed to determine whether correcting hypoalbuminemia can directly improve recovery.

3. Strengthening rehabilitation networks, especially post-acute referral pathways. In Turkey, as in China, rehabilitation access remains uneven, and structured programs could significantly enhance outcomes.

4. Prevention strategies focused on falls in the elderly, including community-level awareness, home safety modifications, and national fall-prevention campaigns.

5. Biomarker-driven prognostic models integrating albumin, hemoglobin, and clinical scores to guide personalized treatment and rehabilitation planning.

Such future studies would not only strengthen evidence-based management but also help establish national guidelines in countries like Turkey, were epidemiological data on TSCI remain limited.

CONCLUSION

This study highlights the changing profile of TSCI, with low falls in older adults emerging as the leading cause and cervical injuries predominating. Functional recovery during hospitalization was strongly associated with higher albumin levels, identifying it as a simple yet valuable biomarker for early prognosis.

Although conducted in Beijing, the findings resonate with challenges faced in other middle-income countries such as Turkey, where rapid population aging is expected to increase the burden of fall-related spinal injuries. Improving preventive measures, early nutritional and hematological assessment, and rehabilitation access should therefore be prioritized to enhance patient outcomes.

In summary, TSCI care requires not only surgical expertise but also a multidisciplinary approach that integrates prevention, metabolic optimization, and rehabilitation. Recognizing albumin as a prognostic factor may help refine treatment strategies and improve recovery pathways in both China and Turkey, ultimately reducing the long-term burden of spinal cord injury on individuals, families, and healthcare systems.

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