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RESEARCH

Spinal cord injury without radiographic abnormality (SCIWORA) in Tianjin, China: a single-center report of 101 cases

Bo Yang[1,2†], Pu Wang[1†], Mengchen Zhang[2], Yang Liu[3] and Fujiang Cao[1*]

Abstract

Study design A retrospective cohort study.

Objective This study aimed to investigate the recent epidemiological characteristics of spinal cord injury without radiographic abnormality (SCIWORA) in adult patients at Tianjin Medical University General Hospital, China, from 2018 to 2022.

Setting Tianjin Medical University General Hospital.

Methods This study included all SCIWORA patients aged ≥ 16 years who were accepted by a general hospital from January 2008 to December 2022. Epidemiological characteristics including sex, age, occupation, etiology, segment of spinal injury, American Spinal Injury Association (ASIA)-ISCoS impairment scale at admission, severity, death and its cause, concomitant injuries and treatment choice were recorded.

Results A total of 101 patients met the criteria for the study. The average age at injury was 54.7 ± 12.3 years (males: 54.7 ± 12.2 years and females: 54.2 ± 12.8 years), with a range of 18–83 years, and the male/female ratio was 4.6:1. The main reason was low falls (53.5%). C4 was the most commonly involved segment. Fifteen (14.9%) patients experienced clinical complications; the most common complication was electrolyte disorder (4.0%), and the most common concomitant injuries were maxillofacial injury (29.7%), followed by head injury (9.9%). Regarding severity, ASIA grade C was encountered most frequently. Surgery was the main treatment choice (84.1%).

Conclusion The epidemiology of adult SCIWORA has unique characteristics. Low falls were the major reason, and the proportion of males was higher. Retired individuals were those at higher risk, and the average age at injury onset was in the middle-aged and elderly range. Surgical treatment was the major treatment choice.

Clinical trial approval Not applicable.

Keywords Epidemiological characteristics, Spinal cord injury, SCIWORA

†Bo Yang and Pu Wang contributed equally.

*Correspondence:
Fujiang Cao
caofujiang@126.com
Full list of author information is available at the end of the article

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Introduction

Spinal cord injury without radiographic abnormality (SCIWORA) was coined in 1982 by Pang and Wilberger in a pediatric population [1].This abbreviation denotes a clinically posttraumatic syndrome in the absence of spinal cord injury on conventional X-rays and/or computerized tomographic (CT) [2]. In 2004, Pang reviewed his work and defined SCIWORA as a posttraumatic symptoms with no evidence of fractures, dislocations, or subluxations on X-ray/CT scans, and further confirmed by MRI to exclude extradural compressive lesions(ligamentous hypertrophy or disc herniation) [3]. Based on previous studies, SCIWORA was initially believed to only affect pediatric patients [4], whereas recent studies have proven that this entity can also occur in adults [5]. Furthermore, the advent of magnetic resonance imaging (MRI) has enabled it to accurately characterize patients diagnosed with SCIWORA [6]. Epidemiological data has also shown the prevalence of SCIWORA is between 13% and 19% in pediatric patients and between 10% and 12% in adults [6, 7].

It is generally considered that the incidence, pathogenesis and severity of adult SCIWORA are different from those of pediatric patients. SCIWORA may have catastrophic consequences. The most typical clinical manifestation of SCIWORA patients is more severe neurological defects in the upper limbs than in the lower limbs [8]. SCIWORA in the majority of adults is caused by hyperextension forces, which may most commonly occur in rear-end accidents or from a direct frontal impact to the face [6, 9]. Elderly patients with degenerative spine conditions (spondylosis or spinal canal stenosis) are predisposed to SCIWORA injuries. Research has demonstrated that the range of increased signal intensity (ISI) reflects the severity for symptom and prognosis for neurologic outcome in patients with SCIWORA [10].

To date, articles and sample sizes concerning the epidemiology of adult SCIWORA are relatively insufficient. To summarize epidemiologic trends and contribute to health care planning for SCIWORA, we identified and reviewed the patients' medical records who underwent SCIWORA and were admitted to Tianjin Medical University General Hospital (TMUGH). The inclusion period was from January 1, 2018, to December 31, 2022.

Patients and methods

This retrospective cohort study included all data from SCIWORA patients in TMUGH were retrospectively identified and reviewed (inclusion time period: January 1, 2018, to December 31, 2022). TMUGH is a tertiary teaching hospital specializing in orthopedics and trauma treatment. The study protocol was subject to approval by the institutional ethics committee. During the 5-year follow-up study period, 101 patients met the criteria of this study.

In this retrospective cohort study, the exclusion criteria (Table 1) were age < 16 years, radiological evidence of trauma (fractures, dislocations, or subluxations), and an associated severe traumatic brain injury.

In our emergency medicine department, all patients were treated under the guidance of the Advanced Trauma Life Support protocols and underwent a radiographic evaluation, including CT and MRI, within 24 h after the injury.

Two researchers collected and analyzed the medical data, including sex and age, length of hospitalization, occupation, etiology, segment of spinal injury, ASIA-ISCoS grade and neurological levels, concomitant injuries, clinical complications, treatment (conservative or surgical approach treatment) and cause of death.

During the analytical process, we classified patients based on their age into six age groups: 16–30, 31–45, 46–60, 61–75 and ≥76 years. Occupations included retired individuals, workers, peasants, staff, freelancers, and students. The types of injuries that led to neurological deficits were divided into complete and incomplete injuries, and paralysis was divided into tetraplegia and paraplegia. The ASIA-ISCoS scale was used to evaluate the severity of motor and sensory functions below the injury. Concomitant injuries such as maxillofacial injury, head injury, fractures of the ribs or limbs and chest injury were reviewed in our study.

Two researchers analyzed the data in a Microsoft Excel spreadsheet and then conducted two cross checks to

Table 1 Inclusion and exclusion criteria of the present study

Inclusion criteria	Exclusion criteria
(1) Age ≥ 16 years or older	(1) Age < 16 years
(2) Positive history of trauma	(2) Radiological evidence of trauma (fractures, dislocations, or subluxations)
(3) Confirmed SCIWORA	(3) Associated severe traumatic brain injury
(Patients presented with neurological deficit plus normal X-ray or CT but abnormal MRI on initial presentation)	(4) MRI evidence of compressive lesions (disc herniation with canal stenosis > 50%, ligamentum flavum hypertrophy)

SCIWORA, Spinal cord injury without radiologic abnormalities

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ensure the accuracy of the information. For statistical analysis, data were performed using GraphPad Prim 8 (GraphPad Software Inc. La Jolla, CA, USA). $p < 0.05$ was considered statistically significant. Continuous data are presented as proportions and mean ± standard deviation (SD).

Results

A total of 101 SCIWORA patients were identified in the medical data, and the numbers in each year between 2018 and 2022 were 27, 26, 12, 18 and 18, respectively (Fig. 1). The mean length of hospitalization was 54.6 ± 14.6 days, with a range of 3–72 days.

Sex and age

We present the age and gender distribution in Table 2. Among all included patients, 82.1% (83) of the patients were male, and 17.8% (18) were female. The ratio of males to females was 4.6:1. The average age at injury onset was 54.7 ± 12.3 years (male 54.7 ± 12.2 years and female 54.2 ± 12.8 years), with a range of 17–83 years. The top two age groups were 46–60 years and 61–75 years, accounting for 75.2%.

Occupations

The occupations of SCIWORA patients included retired individuals (30.7%), workers (21.8%), peasants (16.8%), staff (15.8%), freelancers (13.9%), and students (1.0%). Retired individuals accounted for 30.7% and workers accounted for 21.8%, together accounting for more than half of all included patients (Table 2).
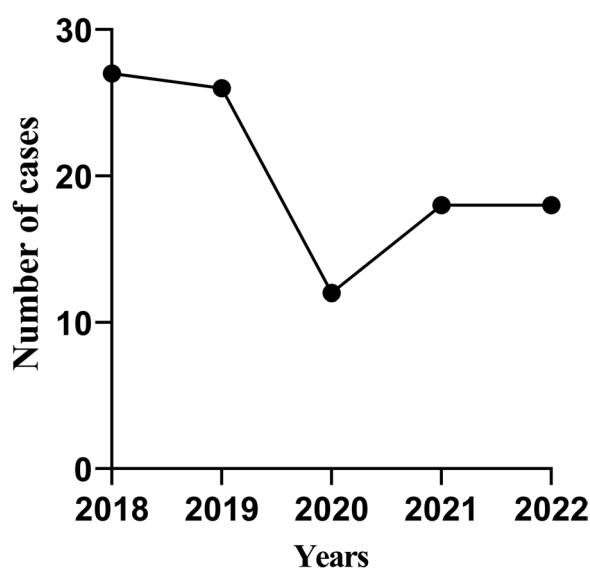

Fig. 1 Annual number of SCIWORA patients during 2018–2022 in Tianjin Medical University General Hospital

Etiology of the injury

Analysis of the acquired data (Table 2) showed that falls (60.4%), including low falls and high falls (53.5% and 6.9%), were the main reason for injury, followed by MVCs (34.6%). High altitude falling objects were the third most common cause (5.0%).

For the group under 76 years old, the low fall morbidity of SCIWORA increased with age (20% for the 16–30-year age group and 70.3% in the 61–75 age group). MVCs were the second cause of SCIWORA and were dominant in the 31–45-year age group (Fig. 2).

Segment of spinal injury

The segment of spinal injury and their distribution modes are represented in Fig. 3, the most common level was C4, followed by C5 accounting for 88.1% and 81.2%, respectively.

ASIA-ISCoS grade and neurological levels

As revealed in Fig. 4, ASIA grade C injuries were the most prevalent (58 cases, 57.4%), followed by grade D (34 cases, 33.7%). Regarding the severity of injury, there were 8 cases (7.9%) of complete tetraplegia, 92 cases (91.1%) of incomplete tetraplegia, and 1 case (1.0%) of complete paraplegia.

The main cause for complete injuries was low falls followed by MVCs accounting for 57.6% and 37.0%, Meanwhile, 77.8% of incomplete injuries were caused by low falls while the remaining cases were caused by MVCs.

Concomitant injuries

The data revealed that 53 patients (43.6%) had concomitant injuries, and the most common concomitant injury was maxillofacial injury (30 cases, 29.7%), followed by head injury (10 cases, 9.9%), fractures of the ribs or limbs (7 cases,6.9%) and chest injury (5 cases,5.0%). MVCs (61.4%) and low falls (27.3%) were the two major causes of concomitant injuries in SCIWORA patients (Table 2).

Clinical complications

Of the 101 patients, clinical complications occurred in 14.9% of SCIWORA patients. Electrolyte disorder (4 cases, 4.0%), DVT (3 cases, 3.0%), respiratory failure (2 cases, 2.0%) and hypoalbuminemia (2 cases,2.0%) were the top three complications (Table 2).

Treatment

Sixteen patients (15.8%) accepted conservative treatment, additionally, the remaining patients (84.1%) accepted surgical treatment. Surgical approaches

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Table 2 Characteristics of patients with SCIWORA in Tianjin Medical University General Hospital, China from 2018 to 2022

	2018	2019	2020	2021	2022	Total
Number of cases	27	26	12	18	18	101
Age (years)						
16–30	0	2	0	3	0	5
31–45	5	3	4	4	3	19
46–60	13	11	3	5	6	38
61–75	8	10	4	6	9	37
76–	1	0	1	0	0	2
Average age	56.4	54.5	53.4	49.9	57.8	54.7 ± 12.3
Hospitalization, days	27.7	18.6	20.5	19.9	18.6	21.5 ± 11.9
Sex						
Male	25	23	8	14	13	83
Female	2	3	4	4	5	18
Etiology						
MVCs	4	8	7	9	7	35
Low falls	18	15	4	7	10	54
High falls	2	2	1	1	1	7
Falling objects	3	1	0	1	0	5
Occupation						
Workers	7	9	0	4	2	22
Staff	6	2	5	2	1	16
Peasants	2	7	3	1	4	17
Retired individuals	11	8	4	4	4	31
Freelancer	1	0	0	6	7	14
Students	0	0	0	1	0	1
ASIA score						
A	1	2	0	1	0	4
B	2	2	1	0	0	5
C	14	13	7	11	13	58
D	10	9	4	6	5	34
Therapy						
Nonoperative	4	5	5	2	0	16
Anterior approach	4	5	3	5	6	23
Posterior approach	19	16	4	11	12	62
Complication						
Wound infection	1	0	0	0	0	1
Electrolyte disorder	1	1	0	0	1	3
DVT	1	1	0	1	1	4
Respiratory failure	1	1	0	0	0	2
Urinary infection	0	1	0	0	0	1
Hypoalbuminemia	0	1	0	1	0	2
Gastrointestinal bleeding	0	0	1	0	0	1
Thrombocytopenia	0	0	0	0	1	1
Associated trauma						
No	21	13	5	9	9	57
Fracture	1	4	0	1	1	7
Head injury	4	2	2	2	0	10
Maxillofacial injury	3	7	6	6	8	30
Chest injury	0	2	0	1	2	5
Severity						
Complete tetraplegia	3	4	1	0	0	8
Incomplete tetraplegia	24	22	11	17	18	92
Complete paraplegia	0	0	0	1	0	1
Incomplete paraplegia	0	0	0	0	0	0

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Table 2 (continued)

ASIA, American Spinal Injury Association; MVCs, motor vehicle collisions; SCIWORA, Spinal cord injury without radiographic abnormality; DVT, Deep venous thrombosis
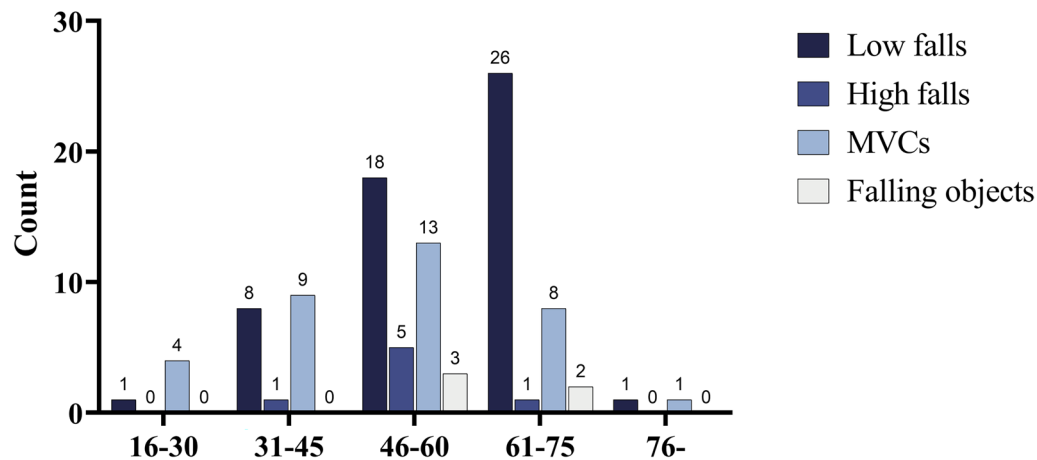
Fig. 2 Percentages of SCIWORA according to age groups by etiology of the injury
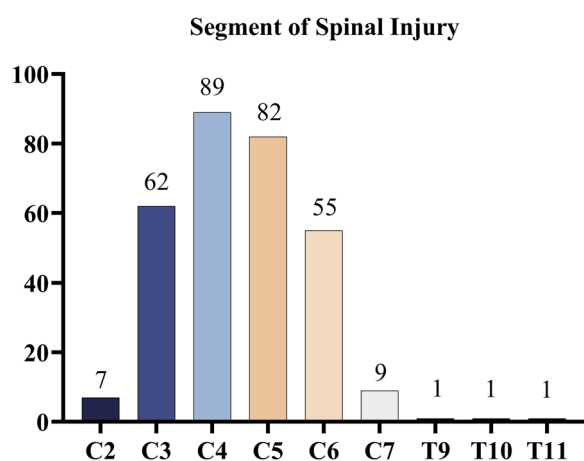
Fig. 3 Distribution histogram of segment of spinal injury of the 101 SCIWORA patients
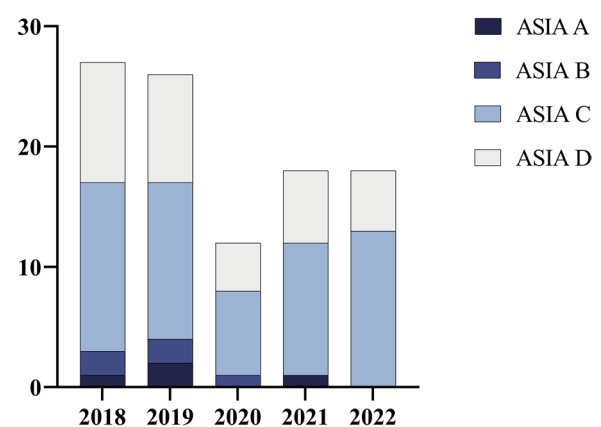
Fig. 4 Distribution histogram of neurological level classified by ASIA ISCoS impairment scale at admission of the 101 SCIWORA patients

included anterior approach (23 cases, 27.1%) and posterior approach (62 cases, 72.9%). The average ages of the conservative treatment group, anterior approach group, and posterior approach treatment group were 50.5, 49.8 and 57.6 years, respectively. The posterior approach group was higher than the anterior approach group ($p < 0.05$). Figure 5 showed a 43-year-old woman experienced limb weakness and numbness in both upper limbs (ASIA grade C impairment) after a low accidental fall, and MRI showed spinal cord hyperintensity at C5-C6 level, no vertebral fracture or ligamentous injury.

Death and the cause of death

Two patients died while in hospital. One patient died before surgery; one patient died after surgery. Both of them suffered cervical injuries from low falls. The first one died as a result of respiratory failure, and another died of respiratory cardiac arrest.

Discussion

Currently, most studies suggest that adult SCIWORA is uncommon and the majority of epidemiological studies on SCIWORA were conducted in pediatric age [11, 12]. However, due to the unique nature of this type of SCI, adult SCIWORA has received increasing attention in
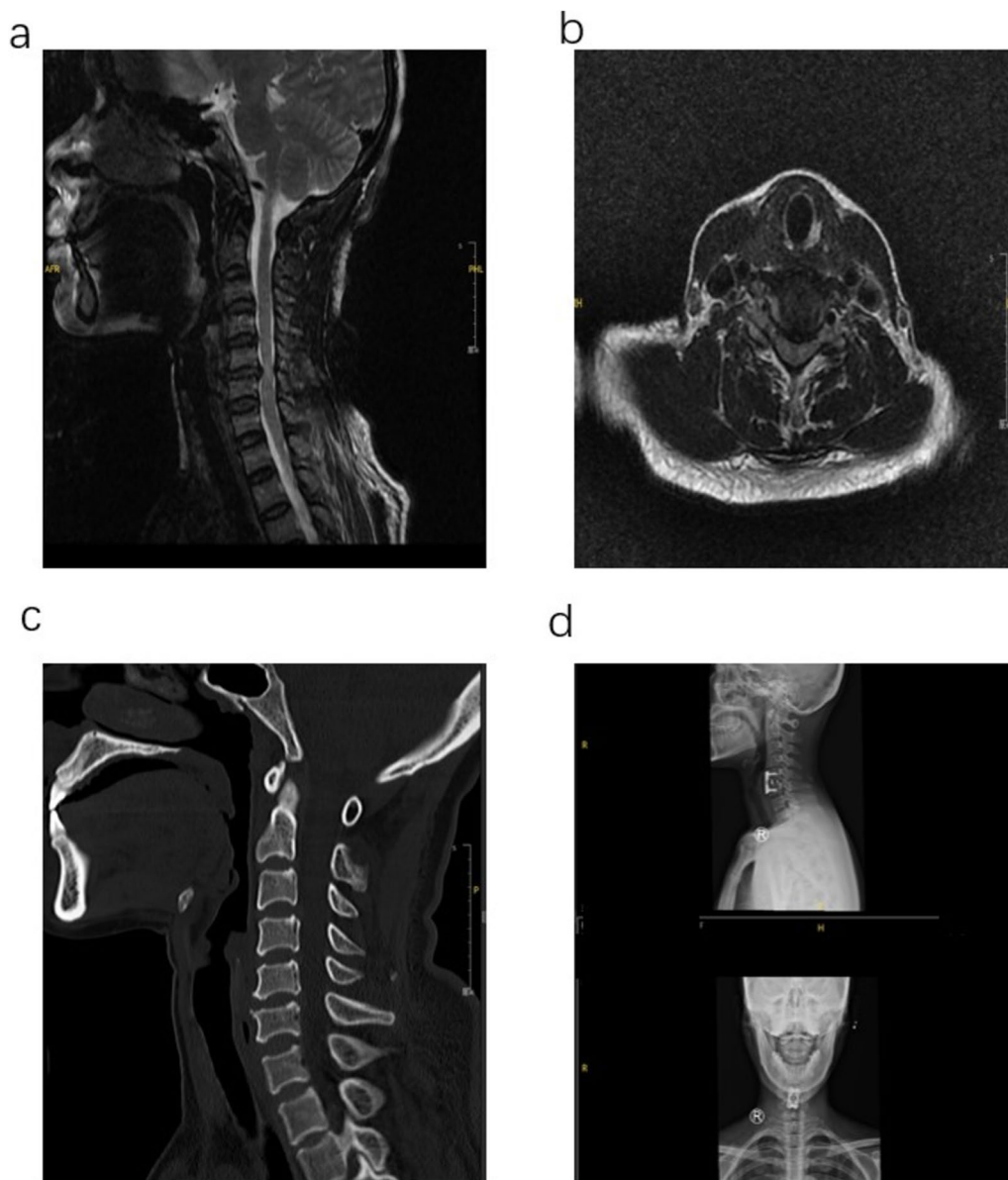
Fig. 5 A 43-year-old woman experienced limb weakness and numbness in both upper limbs after a low accidental fall. **a**: A sagittal T2-weighted image showed spinal cord hyperintensity at C5-C6 level and mild disc herniation in the same segment. **b**: An axial T2-weighted image of this 43-year-old woman. **c**: A two-dimensional computed tomography (2D-CT) showed absence of fracture or dislocation, alongside mild degenerative alterations. **d**: A lateral X-ray after the ACDF(C5-C6) surgery

recent years. Therefore, we describe the epidemiological and clinical characteristics of patients with SCIWORA in TMUGH, as well as the tendency over 5 years.

In this series, the SCIWORA patient counts in each year between 2018 and 2022 were 27, 26, 12, 18 and 18, respectively. In the last three years, we recorded that the number of SCIWORA patients was significantly lower than that in the previous two years. We speculate that this is due to a result of the COVID-19 pandemic and government lockdown measures for the disease, thereby

impacting related trauma occurrences. The average age at injury was 54.7 ± 12.3 years (male 54.7 ± 12.2 years and female 54.2 ± 12.8 years), which was younger than that in previous research [13]. There was no statistical difference in the age of onset between males and females ($p > 0.05$). The highest incidence age group was 46–60, followed closely by the 61–75-year age group in terms of the age at onset. In Qatar, the largest age group was under 45 years [14]. Strong sex-based differences have been observed. Regarding for gender, male patients with SCIWORA

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accounted for the majority. The ratio of male to female SCIWORA patients was 4.6:1, which was higher than that of pediatric patients, and their sex ratio ranged from 1.45:1 to 1.6:1 [15–17]. However, the ratio was less than that in a previous local adult study [13].

Furthermore, we observed that low falls were the primary reason for SCIWORA by screening the etiology of the injury in our series. In this study, the origin of trauma was related to low- energy injury, and accidental fall was the primary reason in the age≥16 group, which was different from that of the pediatric group. Knox elucidated the age-related variations in injury mechanisms in a series of 297 children with SCIWORA. In his study, MVCs were the primary reason for injury in the 0–10-year age group (38–40%). Meanwhile, sports-related injuries were considered as the most common injury mechanism in 11–17-year age group (57%) [18]. In addition, this study also examined the trend of etiology specificity in age stratification (Fig. 4).

Among the total SCIWORA patients aged 75 years or below, the numbers due to MVCs in all patients were stable. Similarly, in our study, the number of adult SCIWORA patients with low falls continued to increase with age. According to reports, falls are also one of the main reasons for TSCIs, especially in later years of life [19, 20], and similarly, the number of patients with SCIWORA caused by low falls continued to increase with age in our study.

Formerly, few studies concerned the occupational status of SCIWORA patients. We analyzed the occupational status: retired individuals and workers accounted for 30.7% and 21.8%, respectively, which is different from Q WU's reports on TSCI [21]. In his reports, the highest proportion was peasants, followed by retired individuals, and then workers. The diversity of occupations might be attributed to the differences in pathophysiology. As is well known, the retirement age in urban China is over 60 years old, thus we should pay more attention to retired individuals.

Regarding the level of injury, C4 was the most commonly involved segment, followed by C5 and C3. Cervical myelopathy had similar distribution characteristics [22]. The theoretical basis of spinal cord fragility is that thoracic and lumbar vertebrae have greater stability in terms of strength and accessory structures than cervical vertebrae. Our study showed a unimodal distribution of injury level. Among them, cervical injury accounted for 99%, and only one case of SCIWORA at the thoracic level was reported. The ultimate data showed that the vast majority of patients had incomplete paraplegia (91.1%). Regarding the SCIWORA severity, we observed the incidence of ASIA C (57.4%) followed by ASIA D injuries, which was inconsistent with the pediatric series and

TSCI series [23, 24]. This result indicated that adult SCIWORA had unique epidemiological characteristics.

In our series, the mortality rate was lower (1.98%) and was related to older age. The direct causes of death were respiratory cardiac arrest and respiratory failure. The incidence of comorbidities and complications in the elderly population was high, and the reserve was low. According to reports, there were higher rates of comorbidities, complications and lower reserve in the older population [25].

Among 101 cases, 16 patients (15.8%) accepted conservative treatment, and 85 patients (84.1%) accepted surgical treatment. However, previous reviews suggest that due to the lack of spinal fractures or dislocations in SCIWORA, conservative strategies, such as immobilization or corticosteroid therapy, are the pillar of therapy [3, 26].

Our results aligned with Qi et al. [27], demonstrated that surgery was the primary clinical treatment for SCIWORA patients, but conservative treatment still played an important role in patients with incomplete spinal cord injury. We speculated that the reason for this is that TMUGH, as the largest medical center in Tianjin, accepted most SCIWORA patients who were recommended for surgical treatment in subordinate hospitals. Based on current data and previous experience, there is still controversy in the literature regarding surgical treatment of SCIWORA. Our results revealed that most patients chose surgery for trying to improve their quality of life.

Nevertheless, this study presented several limitations. (1) As a hospital-based retrospective study, it was unavoidable that some medical data might have been missing. (2) SCIWORA patients younger than 15 years were not regularly attended to in our hospital. Thus, there were no patients aged 0–15 in our data. (3) We could not access patients with severe brain injury because these patients were first admitted to the neurosurgery intensive care unit. (4) Complications had not been fully diagnosed and recorded in medical records. Despite these limitations, we still believe that valuable epidemiological information is contained on our study, enabling us to obtain a deeper understanding SCIWORA.

Conclusions

This study described the epidemiological characteristics of adult SCIWORA patients admitted to TMUGH from January 2018 to December 2022. The data indicated that SCIWORA had unique characteristics. Low falls were the major reason, and the proportion of males was higher. Retired individuals were those at higher risk, and the average age at injury onset was in the middle-aged and elderly range. Surgery was the major treatment choice.

These data may be useful to implement health care planning focused on the characteristics of different groups and pay more attention to high-risk populations.

Data availability
No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate
All procedures were approved by the Authorization of The Ethical Committee of Tianjin Medical University General Hospital (Ethical No. IRB2023-WZ-149). This study complied with the Declaration of Helsinki. Due to the retrospective nature of this study, written informed consent was not required.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

Author details
[1]Department of Orthopedics, Tianjin Medical University General Hospital, Heping District (Anshan Road, No. 154), Tianjin, China. [2]Department of Orthopedics, Tianjin Medical University General Hospital Airport Site, Tianjin, China. [3]Department of Orthopedic Surgery, The Second Affiliated Hospital of Zhejiang University School of Medicine (SAHZU), Hangzhou, China.

References
1. Pang D, Wilberger JE Jr. Spinal cord injury without radiographic abnormalities in children. J Neurosurg. 1982;57(1):114–29.
2. Bonfanti L, Donelli V, Lunian M, Cerasti D, Cobianchi F, Cervellin G. Adult spinal cord injury without radiographic abnormality (SCIWORA). Two case reports and a narrative review. Acta Biomed. 2019;89(4):593–8.
3. Pang D. Spinal cord injury without radiographic abnormality in children, 2 decades later. Neurosurgery. 2004;55(6):1325–42; discussion 1342–3.
4. Meira Goncalves J, Carvalho S, Silva AI, Pereira J, Polónia P. Real spinal cord injury without radiographic abnormality (SCIWORA) in pediatrics: a clinical case report and literature review. Cureus. 2023;15(12): e50491.
5. Tewari MK, Gifti DS, Singh P, et al. Diagnosis and prognostication of adult spinal cord injury without radiographic abnormality using magnetic resonance imaging: analysis of 40 patients. Surg Neurol. 2005;63(3):204–9; discussion 209.
6. Sharma S, Singh M, Wani IH, Sharma S, Sharma N, Singh D. Adult spinal cord injury without radiographic abnormalities (SCIWORA): clinical and radiological correlations. J Clin Med Res. 2009;1(3):165–72.
7. Martinez-Perez R, Munarriz PM, Paredes I, Cotrina J, Lagares A. Cervical spinal cord injury without computed tomography evidence of trauma in adults: magnetic resonance imaging prognostic factors. World Neurosurg. 2017;99:192–9.
8. Kasimatis GB, Panagiotopoulos E, Megas P, et al. The adult spinal cord injury without radiographic abnormalities syndrome: magnetic resonance imaging and clinical findings in adults with spinal cord injuries having normal radiographs and computed tomography studies. J Trauma. 2008;65(1):86–93.
9. Szwedowski D, Walecki J. Spinal cord injury without radiographic abnormality (SCIWORA)—clinical and radiological aspects. Pol J Radiol. 2014;79:461–4.
10. Machino M, Yukawa Y, Ito K, et al. Can magnetic resonance imaging reflect the prognosis in patients of cervical spinal cord injury without radiographic abnormality. Spine (Phila Pa 1976). 2011;36(24):E1568–72.
11. Liu R, Fan Q, He J, et al. Clinical characteristics analysis of pediatric spinal cord injury without radiological abnormality in China: a retrospective study. BMC Pediatr. 2024;24(1):236.
12. Alas H, Pierce KE, Brown A, et al. Sports-related cervical spine fracture and spinal cord injury: a review of nationwide pediatric trends. Spine (Phila Pa 1976). 2021;46(1):22–28.
13. Guo H, Liu J, Qi X, et al. Epidemiological characteristics of adult SCIWORA in Tianjin, China: a preliminary study. Eur Spine J. 2012;21(1):165–71.
14. Yaqoob Hakim S, Gamal Altawil L, Faidh Ramzee A, et al. Diagnosis, management and outcome of spinal cord injury without radiographic abnormalities (SCIWORA) in adult patients with trauma: a case series. Qatar Med J. 2021;2021(3):67.
15. Launay F, Leet AI, Sponseller PD. Pediatric spinal cord injury without radiographic abnormality: a meta-analysis. Clin Orthop Relat Res. 2005;433:166–70.
16. Lee JH, Sung IY, Kang JY, Park SR. Characteristics of pediatric-onset spinal cord injury. Pediatr Int. 2009;51(2):254–7.
17. Liu Q, Liu Q, Zhao J, Yu H, Ma X, Wang L. Early MRI finding in adult spinal cord injury without radiologic abnormalities does not correlate with the neurological outcome: a retrospective study. Spinal Cord. 2015;53(10):750–3.
18. Knox J. Epidemiology of spinal cord injury without radiographic abnormality in children: a nationwide perspective. J Child Orthop. 2016;10(3):255–60.
19. Bárbara-Bataller E, Méndez-Suárez JL, Alemán-Sánchez C, Sánchez-Enríquez J, Sosa-Henríquez M. Change in the profile of traumatic spinal cord injury over 15 years in Spain. Scand J Trauma Resusc Emerg Med. 2018;26(1):27.
20. Zhang ZR, Wu Y, Wang FY, Wang WJ. Traumatic spinal cord injury caused by low falls and high falls: a comparative study. J Orthop Surg Res. 2021;16(1):222.
21. Wu Q, Li YL, Ning GZ, et al. Epidemiology of traumatic cervical spinal cord injury in Tianjin. China Spinal Cord. 2012;50(10):740–4.
22. Lu J, Wu X, Li Y, Kong X. Surgical results of anterior corpectomy in the aged patients with cervical myelopathy. Eur Spine J. 2008;17(1):129–35.
23. Devivo MJ. Epidemiology of traumatic spinal cord injury: trends and future implications. Spinal Cord. 2012;50(5):365–72.
24. Zou Z, Teng A, Huang L, et al. Pediatric spinal cord injury without radiographic abnormality: The Beijing experience. Spine (Phila Pa 1976). 2021;46(20):E1083–8.
25. Brown R, DiMarco AF, Hoit JD, Garshick E. Respiratory dysfunction and management in spinal cord injury. Respir Care. 2006.;51(8):853–68; discussion 869–70.
26. Atesok K, Tanaka N, O'Brien A, et al. Posttraumatic spinal cord injury without radiographic abnormality. Adv Orthop. 2018;2018:7060654.
27. Qi C, Cao J, Xia H, et al. Does cervical curvature affect neurological outcome after incomplete spinal cord injury without radiographic abnormality (SCIWORA): 1-year follow-up. J Orthop Surg Res. 2022;17(1):361.

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