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Original Article

Prognosis of traumatic spinal cord injury in children: Follow-up of 86 patients

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ABSTRACT

Purpose: The long-term situation of children with spinal cord injury (SCI) was investigated, and suggestions for helping them better return to the society were provided.

Methods: SCI patients less than 18 years old hospitalized in Beijing Boai Hospital from January 2011 to December 2020 were retrospectively analyzed. Information including motor function, complications, characteristic changes, self-care abilities, school attendance and social participation were collected by telephone interview and electronic questionnaire. All the answers were statistically analyzed.

Results: A total of 86 cases were enrolled, 77 girls and 9 boys, with a median injury age of 6 years and 2 months. The follow-up time was 3–130 months. The main cause of trauma in these children was sport injury (66.3%), the thoracic spinal cord was involved the most (91.9%), and complete SCIs accounted for the majority (76.7%). In terms of complications, children with complete SCIs were more likely to have urinary incontinence, constipation and characteristic changes ($p < 0.05$); whereas the incomplete SCIs often have spasticity ($p < 0.05$). As to the daily living abilities, children with incomplete lumbar SCIs were more capable to accomplish personal hygiene, transfer, and bathing independently than those with complete injuries, or cervical/thoracic SCIs, respectively ($p < 0.05$). Moreover, children older than 9 years care more able to dress and transfer independently than the youngers ($p < 0.05$). Wheelchair users accounted for 84.9% and more than half of them were able to propel wheelchair independently, and those who move passively in wheelchairs were mostly introverted kids ($p < 0.05$). Almost all (93.8%) children with incomplete injuries were able to walk independently. Most (79.1%) children continued to attending school, and 41.9% participated in interest classes. Unfortunately, 67.4% of the children spent less time playing with their peers than before the injury.

Conclusion: SCIs impair physical structures and function of children, affect their independence in daily living, and restrict school attendance and social interaction. Comprehensive rehabilitation after injury is a systematic work. Medical staff and caregivers should not only pay attention to neurological function, but also help them improve self-care abilities. It is also important to balance rehabilitation training and school work and social participation.

Introduction

Traumatic spinal cord injury (SCI) is rare in children[1] but causes great harm to children and their families. Immature spine has a larger inherent elasticity and range of motion, and vertebrae can reset themselves after dislocation caused by external forces.[2] Therefore, there is always no spine fracture or dislocation in children. Pang et al.[3] proposed the concept of "spinal cord injury without radiographic abnormalities (SCIWORA)" in 1982, which is also known as "spinal cord injury without fracture or dislocation". In other words, there is no fracture or dislocation of spine on X-ray films or CT scans, but abnormal signals of spinal cord in MRI can be discovered. It has been reported that SCIWORA occurs mostly in the cervical spinal cord in children, and traffic accident is the main cause.[4–6] However, in China, SCIWORA tends to occur in the thoracic spinal cord, and sports injuries are more common,[7] especially those caused by hyperextension of spine during dancing. SCI

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not only causes sensorimotor dysfunction below the injury level, but also results in many complications,[8] which greatly affects the physical and mental health of the injured. Children are in a critical period of growth and development, and SCI can affect all aspects of their lives, bringing tremendous pressure and economic burden to caregivers.[9]

In 2001, the World Health Organization introduced the International Classification of Functioning, Disability and Health (ICF).[10] It advocates treating these patients as an integrated individual including body structures, function, activities and participation associated with him/her. So far, there were a few reports on neurological and radiological changes after SCIWORA in children, yet they seldom focused on changes of activities and participation. Therefore, it is important to follow up a large sample of SCIWORA children to observe the long-term aspects. In this study, children with SCIWORA were followed up based on the concept of above mentioned ICF. This study was expected to investigate the long-term impact of injury on children's health and life, analyze the causes and put forward suggestions for the caregivers and medical staff.

Methods

Participants

This study was approved by the Ethics Committee of Drug Clinical Trial Institution of China Rehabilitation Research Center. Children with SCIWORA hospitalized in Beijing Boai Hospital from January 2011 to December 2020 were selected. Inclusion criteria: (1) Injury age < 18 years old. (2) Complete medical records with detailed injury and clinical diagnosis. (3) Definite traumatic history. (4) X-ray films or CT scans showing no spine fracture or dislocation. Exclusion criteria: (1) Spine fracture or dislocation could be found. (2) SCI was caused by congenital factors, dysplasia, tumor, infection or others, such as myelitis, tethered cord syndrome, spinal arteriovenous malformation, etc. (3) Children or caregivers refused to participate in the follow-up investigation.

Patients data

A total of 86 children with traumatic SCIWORA were followed up, including 77 females (89.5%) and 9 males (10.5%). The present age ranged from 3 years and 8 months to 19 years, with a median of 9 years and 2 months. The age of patients at injury ranged from 1 year and 2 months to 11 years, with a median of 6 years and 2 months. The follow-up time was 3 – 130 months, with a median (Q_1–Q_3) of 38 (24–57) months. The information of the patients was obtained from medical records, telephone interviews with the caregivers and questionnaire. Caregivers are instructed to fill out the questionnaire truthfully. In order to obtain all-round data, the questionnaire was determined by senior physicians majoring in spine and SCI, based on reviewing literature and clinical assessment tools and their clinical experience. The questionnaire covered complications, self-care activities and ability to participate in social activities (Appendix A). Information on injuries is subject to medical records. The causes of injury were classified according to the etiology of traumatic SCI in the International Spinal Cord Injury Core Dataset (version 2.0).[11] In this study, the injury severity of each patient was rechecked by reviewing physical examination in the medical records, and was classified as “complete” or “incomplete” depending on whether sensory and/or motor were preserved at the sacral segments S_4 – S_5, according to the International Standards for Neurological Classification of Spinal Cord Injury (2011).[12]

Statistical analyses

SPSS 26.0 (the Statistical Package for the Social Sciences, SPSS Inc., Chicago, IL, USA) and GraphPad Prism 8.0 (GraphPad Software Inc, San Diego, USA) were used for statistical analysis. For measurement data conforming to normal distribution, mean ± standard deviation was used to describe the data, and *t*-test was used for comparison between groups. Counting data were expressed as frequency and rate, Chi-square test was used for inter-group comparison, and Bonferroni correction was used for post-test when there were differences between multiple groups. $p < 0.05$ indicated that the difference was statistically significant.

Results

Demographic characteristics

The main cause of trauma in this study was sports injury, especially hyperextension during dancing (80.7%, 46/57). Most of children had complete thoracic SCI (Table 1).

Physical structure and function

Motor function

All incomplete injury had preserved strength of extremities. Only children with cervical SCI were classified as American Spinal Cord Injury Association Impairment Scale (AIS) grade D, which enables functional activities of upper extremities. Among the children with thoracic and lumbar SCIs, 14 children were able to walk independently, 2 children could walk with the assistance of caregivers or instruments, and only 1 child had voluntary movement of lower extremities but no functional activities.

Complications

Spasticity

Sixteen patients (18.6%) had spasticity at lower extremities. Children with higher injury level were more likely to have spasticity ($p = 0.040$), and the incidence of incomplete injury was higher than that of complete injury ($p < 0.05$) (Table 2).

Neurogenic bladder/bowel

For urination, 56 children (65.1%) received intermittent catheterization, most (41 cases, 73.2%) at a frequency of 4 – 5 times a day. Twenty-seven patients (31.4%) were able to urinate voluntarily, and only 3 patients (3.5%) had indwelled catheter. Sixty cases (69.8%) had urinary incontinence (Fig. 1). The incidence of urinary

Table 1
Demographic characteristics of 86 SCIWORA children.

Variables	Cases (*n*, %)
Sex	
Male	9, 10.5
Female	77, 89.5
Causes	
Sports	57, 66.3
Falling	19, 22.1
Traffic accidents	10, 11.6
Injury level	
Cervical	1, 1.2
Thoracic	79, 91.9
Lumbar	6,6.9
Injury degree	
Complete	66, 76.7
Incomplete	20, 23.3

SCIWORA: spinal cord injury without radiographic abnormalities.

Table 2
The relationship between the incidence of complications and the severity, level and the time after injury.

Index	Injury severity				Injury level				Age at injury (year)			
	Complete ($n = 20$)	Incomplete ($n = 20$)	χ^2 value	p value	Cervical/Thoracic ($n = 80$)	Lumbar ($n = 6$)	χ^2 value	p value	≤ 6 ($n = 39$)	> 6 ($n = 47$)	χ^2 value	p value
Spasticity	7 (10.6%)	9 (45.0%)	9.8	0.002	13 (16.3%)	3 (50.0%)	4.2	0.040	7 (17.9%)	9 (19.1%)	0.2	0.887
Urinary incontinence	51 (77.3%)	9 (45.0%)	7.6	0.006	57(71.3%)	3(50.0%)	1.2	0.274	27 (69.2%)	33 (70.2%)	0.1	0.921
Constipation	53 (80.3%)	9 (45.0%)	9.5	0.002	59 (73.8%)	3 (50.0%)	1.6	0.211	30 (76.9%)	32 (68.1%)	0.8	0.363
Pressure ulcer	17 (25.8%)	1 (5.0%)	2.8	0.092	17 (21.3%)	1 (16.7%)	0.1	0.78	6 (15.4%)	12 (25.5%)	1.3	0.249

incontinence was higher in children with complete injury than in those with incomplete injury ($p < 0.05$) (Table 2). Sixty-two cases (72.1%) had constipation, and the complete injury cases occupied the majority ($p < 0.05$) (Table 2).

Pressure ulcers

Eighteen patients (20.9%) had pressure ulcers on at least one region. They were commonly seen at buttock skin (sacrococcygeal region/ischial tubercles) (13 cases, 72.2%), followed by heel (7 cases, 38.9%), posterior thigh (4 cases, 22.2%), posterior leg (3 cases, 16.7%) and popliteal fossa (2 cases, 11.1%).

Characteristic change

About half of the patients (36 cases, 41.9%) were found more introverted than before injury, and most of which were complete injury children (33 cases, 91.7%, $p < 0.05$). Some of them (20 cases, 55.6%) also communicated with their parents less than before the injury.

Self-care abilities

The median present age of all children in this study was 9 years and 2 months, so the children were divided into "$\leq$ 9 years old" and "> 9 years old" groups for analysis. The ability to complete personal hygiene, and be transferred independently of children with incomplete lumbar SCI was significantly better than that of children with complete cervical/thoracic SCI. Children > 9 years old had significantly better ability to independently complete dressing and be transfered than those $\leq$ 9 years old (Table 3).

In terms of mobility, 84.9% (73/86) of the children were wheelchair dependents, of which 67.1% (49/73) could propel wheelchair independently, including the only one child with cervical SCI, 58.2% (46/79) with thoracic SCIs, and all with lumbar injuries. Independent walkers accounted for 11.4% (9/79) and 66.7% (4/6) of the children with thoracic and lumbar SCIs, respectively (Fig. 2). All the children with complete injuries were wheelchair users, and 24 of them (36.4%, 24/66) were able to walk with assistance. Most of the children with incomplete injury (70.0%, 14/20) could walk independently, and only a few (35%, 7/20) needed a wheelchair (Fig. 3). In addition, the results showed that fewer children who could propel wheelchairs independently became introverted, which was statistically significant compared with those who were dependently ($p < 0.05$).

Social participation

After injury, 68 cases (79.1%) returned to school and 14 cases (16.3%) were taught by home visiting teachers or parents. Among those who did not continue to attend to school, 61.5% (8/13) were still seeking treatment, while the rest were restricted by environmental or economic factors. In terms of leisure and entertainment, 36 children (41.9%) participated in interest classes. More than half (58 cases, 67.4%) of the children spent less time interacting and playing with their peers than before injury, but most of them (40 cases, 69.0%) were still happy when playing.

Discussion

Physical structure and function

In the present investigation, sports injury was the main cause of SCIWORA in children. This injury is most common in girls, when performing hyperextension of spine during dancing. The likely mechanism was reported to be the ischemic changes[7] in the

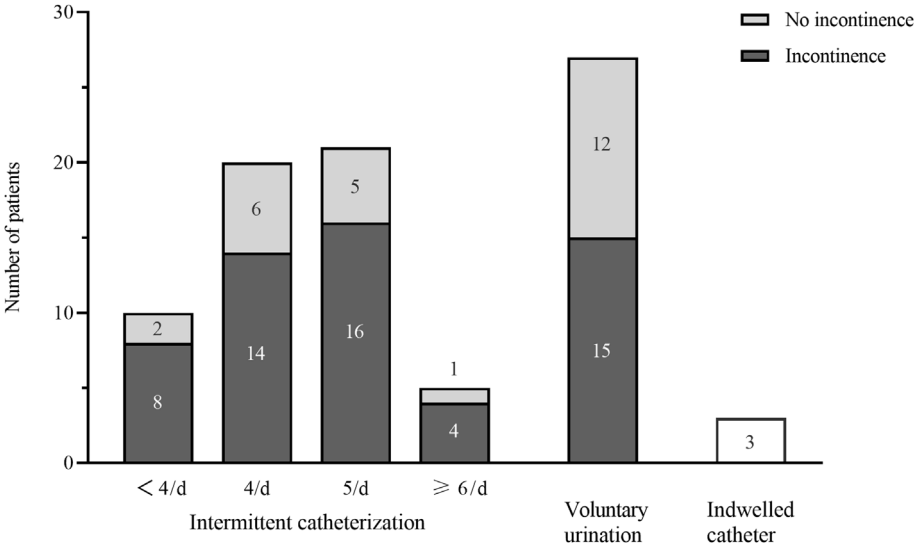

Fig. 1. Urination pattern and proportion of incontinence of 86 spinal cord injury without radiographic abnormalities children.

Table 3
Relationship between independence of self-care and the severity, level of injury and present age.

Index	Injury severity				Injury level					Present age			
	Complete ($n = 66$)	Incomplete ($n = 20$)	χ^2 value	p value	Cervical ($n = 1$)	Thoracic ($n = 79$)	Lumbar ($n = 6$)	χ^2 value	p value	≤ 9 years old ($n = 41$)	> 9 years old ($n = 45$)	χ^2 value	p value
Feeding	51 (77.3%)	18 (90.0%)	0.9	0.352	1 (100%)	63 (79.7%)	5 (83.3%)	0.3	0.863	32 (78.0%)	40 (88.9%)	1.9	0.174
Dressing	45 (68.2%)	18 (90.0%)	3.7	0.053	1 (100%)	57 (72.2%)	5 (83.3%)	0.7	0.636	9 (22.0%)	20 (44.4%)	4.9	0.028
Personal hygiene	11 (16.7%)	15 (75.0%)	22.8	< 0.001	0	21 (26.6%)	5 (83.3%)	9.0	0.011	28 (68.3%)	38 (84.4%)	3.1	0.077
Transfer	14 (21.2%)	17 (85.0%)	27.1	< 0.001	1 (100%)	25 (31.6%)	5 (83.3%)	8.3	0.016	11 (26.8%)	22 (48.9%)	4.4	0.036
Bathing	5 (7.6%)	13 (65.0%)	30.6	< 0.001	0	14 (17.7%)	4 (66.7%)	8.3	0.015	6 (14.6%)	12 (26.7%)	1.9	0.171

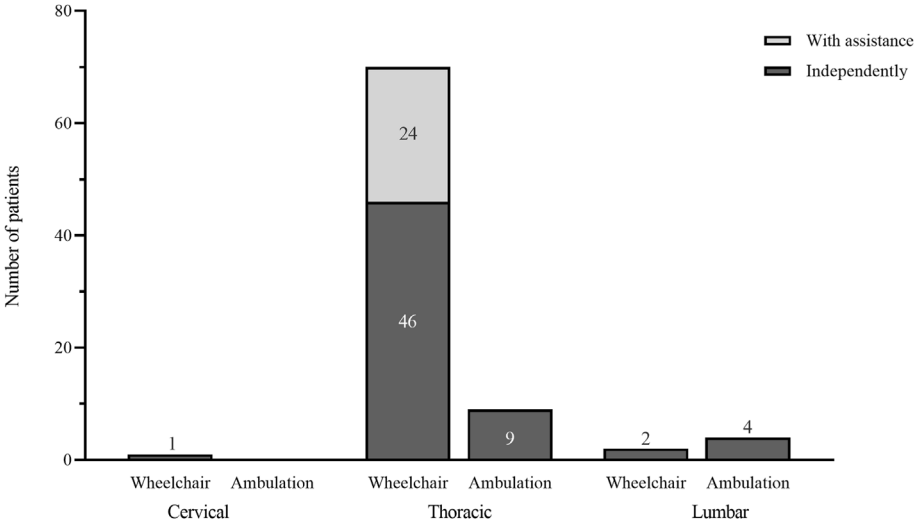

Fig. 2. Mobility of spinal cord injury children with different injury levels.

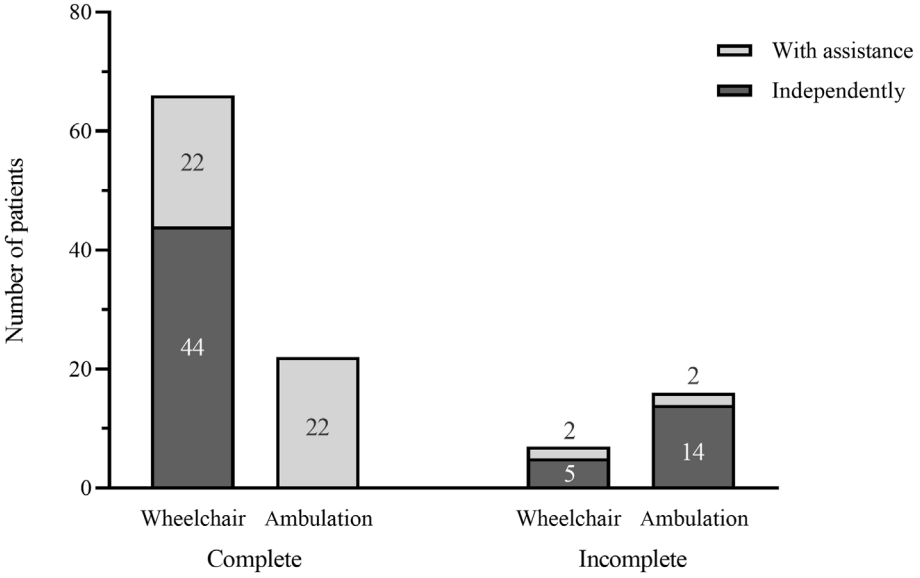

Fig. 3. Mobility of spinal cord injury children with different severity of injury.

narrowest thoracic spinal canal and the long and thin spinal cord with insufficient blood supply,[13] where SCIWORA tends to develop. SCI leads to obvious motor dysfunction and different severity of injury affects the recovery of motor abilities. This study showed that children with complete injury still had no voluntary movement of extremities below the injury level, while most of the children with incomplete injury could walk independently. In our study, one child with AIS grade B could walk independently 3 years after the injury. Wang et al.[14] observed 6 children with SCIWORA (1 complete injury and 5 incomplete injuries), and found that those

with complete injury had no recovery of motor function, while the children with incomplete injury had obvious recovery of motor function. Two months after injury, one child with AIS grade B recovered to grade E.

Complications of SCI

In this study, children experienced complications of SCI such as spasticity, pressure ulcers, and neurogenic bladder and bowel, while the complete injuries were more prone to complications besides spasticity. This was consistent with the research results of Schottler et al.[15] About one-fifth of children develop pressure ulcers after SCI. Due to sensory disorders, children are unable to perceive the numbness or pain that were caused by prolonged compression and followed blocked blood circulation of skin, especially at the apophysis. Most of children in this study had complete thoracic SCI, who had to always stay in bed or in a wheelchair for daily activities. Their buttock skin, especially the sacrococcygeal region and ischial nodules, continued to bear the weight, and then were prone to pressure ulcers. It is necessary for caregivers to help children regularly change positions and inspect skin as prevent.

Neurogenic bladder is one of the common complications after SCI, which is characterized by uncoordinated activities of detrusor and sphincter. Detrusor overactivity leads to stress urinary incontinence,[16] seriously affecting the quality of life in children. Effective bladder management can reduce detrusor tension, maintain urinary storage in bladder, and prevent ureteral reflux from damaging renal function through regular and adequate urine drainage.[17,18] Self-cleaning intermittent catheterization combined with oral medication is an important measure of self-management of bladder in SCI children.[19,20] European Association of Urology Neuro-Urology guidelines[21] recommends intermittent catheterization of 4–6 times a day for SCI patients to reduce the incidence of urinary tract infections. This study found that most children needed intermittent catheterization with a frequency of 4–6 times a day, and 70% of children had urinary incontinence. Three children had indwelled catheter and replaced regularly because of the inability to perform intermittent catheterization. It must be emphasized here that both the children and caregivers should be educated about the purpose of bladder management, importance of drugs and intermittent catheterization and needs of mastering proper catheterization methods. After injury, it was difficult for children to confront and accept their differences from others, such as intermittent catheterization and the use of diapers. On the other hand, limited activities and participation may also lead to personality changes in children. Relevant studies have shown that SCI has a long-term and profound psychological impact on children, which not only results in post-traumatic stress disorder in childhood,[22] but also may lead to abnormal behaviors such as alcohol and drug abuse, and unhealthy mental states such as anxiety and depression in adulthood.[23,24] In this study, quite a number of children became introverted because of injury, which reduces their communication with the outside and even their families.

Besides spasticity, pressure ulcer, urine incontinence and constipation, children with SCI are also prone to scoliosis, hip abnormalities, osteoporosis, vesicoureteral reflux and etc. Diagnosis of most of these complications requires the help of laboratory and imaging examination. This study, due to the limited objective conditions, could not accurately diagnose and evaluate the above mentioned complications.

Self-care and social participation

Motor function of upper extremities was not affected in the children with thoracic and lumbar SCI in this study, but some of them were still unable to live independently (for example, 14 and 21 children were unable to complete feeding and personal hygiene by themselves, respectively). Communicating with caregivers helped us to know that this might be attributed to the excessive assistance provided by them. Rehabilitation physicians and therapists should guide caregivers to provide appropriate amount of assistance to improve the independence of mobility and activities of daily living for children.

This investigation showed that all children with complete injury used wheelchair, and a few could walk with assistance such as knee-ankle-foot orthosis and rehabilitation robots. Most of the children with incomplete injury can walk independently, but a few still rely on wheelchairs. It can be explained not only by severity of injury, but also by overprotection from caregivers. The meticulous care to children by a family member can sometimes backfire and reduce independence of children. While walking, the gravity load will further stresse blood vessels and bones by stimulating muscle contraction, which helps to avoid complications such as muscle atrophy, deep venous thrombosis and bone loss.[25] Therefore, on the premise of ensuring the safety, caregivers should encourage children to do standing and walking training as soon as possible.

Childhood life was composed mainly of studying and playing. Unfortunately, SCI prevents children from returning to school and participating in society. In this study, because parents attach importance to education, most children can continue to go to school normally, and a small number of children can only receive education by visiting teachers or parents due to serious injury, environmental or economic constraints. There were 8 children who drop out of school because they are still accepting treatment. Almost all of children during follow-up had thoracic and lumbar SCI, but the motor function of the upper limbs and cognitive ability were intact. They are equipped with learning abilities like normal kids. The recovery of physical function in children with SCI can occur within 2 years after the injury,[26] and it is of great significance for children to carry out rehabilitation training during this period. One of the 8 children who continued to seek medical care had been injured for more than 2 years. What important for these children is acquiring life skills and return to the life as soon as possible. Caregivers should learn to understand the injury itself and relevant knowledge, so as to arrange a reasonable time of receiving rehabilitation and going back to school for children.

Children with complete injury could not attend interest classes or play with their peers because they are forced to use wheelchairs, which restrict their mobility, reduce communication with the outside and result in a more introverted personality. But even with limited games, most of them still enjoyed it. Though children with SCI have got to use wheelchairs, they are potential in independently operating at an early age,[15] and thus rehabilitation physicians should carry out training about wheelchair operation skills immediately. Caregivers need to reduce assistance when children are capable, encourage them to propel wheelchairs and participate in entertainment, help them to increase self-confidence and prevent depression.[27]

The questionnaires used in this follow-up survey were designed based on the following studies, which were closely related to children's lives and made positive recommendations. Ability of doing activities and participating of SCI children has been widely concerned. Slavin et al.[28] developed the Pediatric Spinal Cord Injury Activity Measurement scale to reasonably evaluate children's mobility from daily activities, wheelchair mobility, ambulation and other aspects. The United States has developed the International Spinal Cord Injury Pediatric Activity and Participation Basic Data Set,[29] including physical function, activities of daily living and participation, which is used to comprehensively assess children's ability of feeding, dressing, toileting, outing with family and friends,

etc. Calhoun et al.[30] identified 3 dimensions for evaluating activities and participation in children after SCI: mobility (wheelchair/walking), self-care (feeding/dressing/toileting) and entertainment (self/with family/with peers).

There are several limitations of this study. It is difficult to quantitatively analyze the data obtained by telephone interview and questionnaire. Most of children returned to the local area to live or seek medical treatment after discharge, so it is hard for researchers to conduct detailed evaluation, including uninvestigated complications mentioned above. To ensure the authenticity of the data, we obtained injury information from medical records. The contents of the questionnaire were determined based on former research and clinical experience. Although the questions are explained in non-technical terms and most of the questions are presented in a multiple-choice format to avoid bias from caregivers' descriptive answers, they are not direct assessments and are mostly objective lay answers with low reliability.

In conclusion, the results of this study showed that SCIWORA in children causes motor dysfunction and related complications that affect the physical structure and function, and limit children's self-care abilities, school attendance and social participation. Comprehensive rehabilitation after SCI requires the cooperation of children, medical staff and caregivers, to help the children adapt to the changes brought by injury and reintegrate into the life and society as early as possible.

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Ethical statement

The authors certify that all applicable institutional and governmental regulations concerning the ethical use of medical records were followed during the course of this research.

Declaration of competing interest

The authors declare that they have no conflict of interest.

Author contributions

The study was designed by Jun-Wei Zhang and Yi Hong. Yu-Fei Meng and Jun-Wei Zhang wrote the main text. He-Hu Tang, and JinZhu Bai helped to prepare the tables. Fang-Yong Wang, Shu-Jia Liu, and Zhen Lyu helped to prepare the figures. Shi-Zheng Chen and Jie-Sheng Liu helped to prepare the references. Each author carefully reviewed the manuscript and agreed with the final version.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.cjtee.2022.05.001.

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