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REVIEW ARTICLE

Guidelines for treating spinal cord injury without radiological abnormalities in children

Ruba Altahla[1], Jamal Alshorman[2], and Xu Tao[1]*

[1]Department of Rehabilitation, Tongji Hospital, Tongji Medical College, Huazhong University of Science and Technology, Wuhan, China

[2]Department of Orthopedics, Union Hospital, Tongji Medical College, Huazhong University of Science and Technology, Wuhan, China

Abstract

Spinal cord injury without radiological abnormality (SCIWORA) is a rare condition that predominantly affects children. The enigmatic nature of SCIWORA poses significant challenges in terms of diagnosis, treatment, and achieving full recovery. Various factors, such as different injury mechanisms, delayed symptom onset, normal magnetic resonance imaging findings in certain cases, and complex management decisions, contribute to the challenges of dealing with SCIWORA. Attaining a significant outcome and complete recovery through a single-treatment approach is difficult. Therefore, a multifaceted treatment strategy is proposed to yield more favorable results. This paper comprehensively addresses the assessment and management, examination and diagnosis procedures, treatment methods, rehabilitation techniques, and potential complications associated with SCIWORA in children. The paper provides therapeutic guidance for physicians and medical staff, with the aim of enhancing survival rates and improving recovery outcomes. Moreover, it offers suggestions for restoring neurological functions in pediatric patients suffering from SCIWORA.

Keywords: Spinal cord injury without radiological abnormality; Pediatrics; Magnetic resonance imaging; Surgery; Therapeutic treatment; Rehabilitation

***Corresponding author:**
Xu Tao
(i202122089@hust.edu.cn)

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1. Introduction

The original description of spinal cord injury without radiological abnormality (SCIWORA) was first published in 1982[1]. SCIWORA is a rare disease that primarily affects children but also occurs in adults, with a higher prevalence in children due to anatomical differences and the mechanism of injury (MOI). In children outside of China, 75% of spinal cord injuries (SCIs) are attributed to violent trauma, such as sports-related injuries, child abuse, motor vehicle accidents, falls, and diving accidents. Conversely, in China, 50% of cases result from nonviolent trauma during dance training, particularly related to backbend movements[2]. The underlying mechanism of SCIWORA in children is complicated and differs from that in adults[3]. The biomechanics of the pediatric spine plays an important role in this condition. Compared to adults, the higher elasticity of the children's spine increases the risk of developing SCIWORA. Factors such as flexion, hyperextension, longitudinal distraction, and ischemia can contribute to SCIWORA in

children. When children engage in repetitive backbend movements, dynamic compression of the spinal vessel, and longitudinal traction of the spine during sustained or repeated hyperextension play critical roles in the onset of SCIWORA. Magnetic resonance imaging (MRI) serves as the gold standard for diagnosis and prognosis evaluation, although it may initially show a normal appearance. In addition, the symptoms of SCIWORA can exhibit delayed onset, and there is a possibility of recurrence[4,5]. Education and awareness are imperative for accurate diagnosis, treatment, prevention, and mitigation of further neurological function deterioration. Timely management of SCIWORA is essential to prevent secondary injury. At the same time, treatment decisions and management should be tailored on a case-by-case basis[6]. This article aims to provide essential insights into SCIWORA in children, assisting practitioners in achieving precise diagnoses and significant prognoses.

2. MOI

The pediatric spine exhibits significant differences from the adult spine, rendering the spinal cord susceptible to injury due to factors such as flexion, hyperextension, longitudinal distraction, and ischemia. The MOI underlying SCIWORA remains unclear, as some patients initially present with normal MRI findings. SCIWORA can be categorized based on the cause of injury:

i. SCIWORA caused by violent trauma (motor vehicle accidents and sports-related incidents), which has been reported by many researchers
ii. SCIWORA caused by minor trauma.
iii. Many children engage in backbend movement (repetitive hyperextension of the spine) during dance training (Figure 1). This practice is common Chinese dance training and bears similarities to movements commonly performed during surfing. Some children suffer non-traumatic SCIWORA, necessitating differential diagnosis to rule out conditions such as arteriovenous malformation, multiple sclerosis, acute transverse myelitis, acute disseminated encephalomyelitis, infarction, intramedullary neoplasms, and myelin oligodendrocyte glycoprotein antibody-associated disease[2,7-9]. External forces acting on the pediatric spinal column often do not result in fractures but instead cause elongation, gliding, and vertebral slippage. Longitudinal traction of the spine leads to violent distraction of the spinal cord, causing nerve fiber rupture[10]. Simultaneously, sustained or repeated hyperextension of the spine during dance training can lead to dynamic compression of the spinal vessel, resulting in vascular injury, venous hypertension, and venous congestion, ultimately leading to spinal cord ischemic injury. At present, the MOI following sustained or repeated hyperextension of the spine is believed to be caused by spinal cord ischemic injury, which exhibits similarities to a surfer's myelopathy.

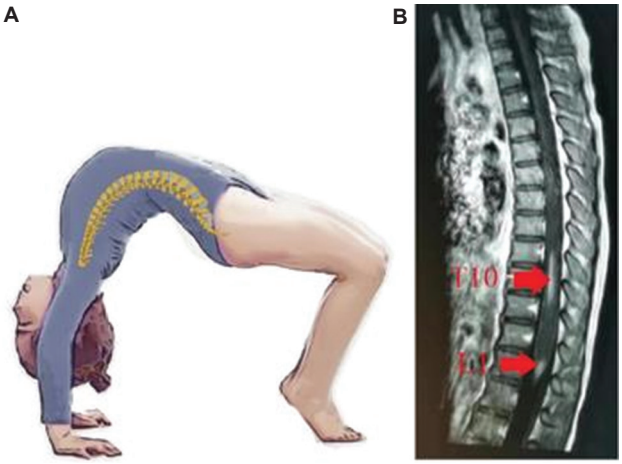


Figure 1. Backbend movement. (A) Children's hyperextension and spine shape; (B) spinal cord injury at T9 – T10, involving transient slippage of the apical vertebral body and facet joints, lateral compression injury of the spinal cord by the anterior and posterior ligaments, excessive longitudinal traction injury concentrated at the junction of the cauda equina and conus (similar to the different mechanics of the tendon-muscle body), and interfacial stretch injury.

3. Assessment and management

Managing SCIWORA in children, especially those aged ≤8 years old, poses several challenges[11]. SCIWORA encompasses traumatic myelopathy, a condition not associated with visible vertebral fractures or ligamentous abnormalities on ordinary radiographs and computed tomography (CT) scans, with some cases even presenting normal MRI findings[4,5,12]. These distinct case profiles exhibit significant variations in their presentation, medical management, and final neurologic outcome[13]. In the early period following onset, SCIWORA patients should undergo a neurological examination to assess sensorimotor functions and determine the appropriate treatment method. The American Spinal Injury Association Impairment Scale (ASIA) is recommended for evaluating their quality of daily life. ASIA is widely used as a quantitative diagnostic classification tool for neurological assessment post-SCI[14,15]. Early identification and evaluation of neurological deficits facilitate a deeper understanding and early intervention of each case[16]. Neurological deficits tend to worsen progressively and should be subject to repeated evaluations. The neurological dysfunctions typically reach their nadir after 8 – 24 h. Therefore, a case-by-case evaluation is essential before initiating SCIWORA management[17]. The evaluation of these cases goes beyond the ABCs of resuscitation[18].

4. Imaging examination

Accurate imaging is vital for diagnosing SCIWORA in children. This section explores imaging techniques and their role in diagnosis and management.

i. X-ray imaging: The essential steps involve performing anterior-posterior, lateral view, and open-mouth X-rays. While X-ray imaging shows the alignment of the spinal column, it may not be sufficient for detecting many pathological changes in cases of SCIWORA.

ii. CT scans serve as the gold standard for evaluating and screening spine fractures, offering superior sensitivity and specificity in detecting bone abnormalities[19]. They offer enhanced and accurate details for identifying fracture types and bony abnormalities[20]. The use of multi-detector CT not only improves precision but also accelerates imaging compared to older CT technologies, making it an effective method for detecting vertebral fractures[21]. In addition, axial and 3D views in the CT scans are valuable tools for illustrating spinal canal shape, assessing facet joint stability, and distinguishing small, hidden lesions that may not be apparent on X-ray images[22,23].

iii. MRI becomes a routine examination when X-ray and CT results are normal, and it is the preferred method for determining the integrity, location, severity, and involvement of structures such as the intervertebral disk, ligaments, cauda equina, and nerve roots[24,25]. The T2-MRI signal allows for differentiation between edema, contusion, or ischemia (high signal) and hemorrhage (low signal), making the T2-MRI image the most valuable diagnostic tool for SCIWORA diagnosis[26,27]. Moreover, it is essential not to restrict MRI to a single vertebral level[28]. MRI stands as the best choice for assessing the severity of SCIWORA, and it is important to perform MRI examinations at every follow-up visit[29]. In addition, performing follow-up MRIs can reveal dynamic pathological changes in the spinal cord. Examining the entire spine can be particularly helpful in identifying soft-tissue injuries and micropathological abnormalities. Early MRI scans offer some advantages, especially in cases of severe injury, that may reveal pathological changes[30]. The extent of edema on MRI is not consistent with neurological injury level. In certain cases, features of spinal cord abnormalities may only become apparent on MRI after 1 – 2 days[31]. The timing of MRI scans has proven to be critical; serial scans can detect active intramedullary and extramedullary lesions and signal variations, or previously undetected anomalies. MRI is capable of revealing transaction, contusive hemorrhage, traumatic edema, and concussion[32]. Many cases of SCIWORA showed no abnormalities on MRI, leading to their classification as "real SCIWORA"[9,13,28]. The "real SCIWORA" syndrome is a condition that necessitates a complete spinal MRI to rule out structural and potentially dangerous causes of neurologic dysfunction[33]. Furthermore, various quantitative MRI techniques, including diffusion tensor imaging (DTI), can indicate micropathological changes in white matter (WM) by observing the diffusion direction and distribution of water molecules. More precisely, DTI provides an evaluation of injury severity, location, and classification[34-38]. However, to confirm a SCIWORA diagnosis, it is essential to conduct multiple MRI examinations or incorporate other imaging techniques, such as MRA.

5. Diagnosis

The diagnosis of SCIWORA should be based on an evaluation of the patient's symptoms and, subsequently, an assessment of the stability of the bony structures, with the exclusion of fractures, dislocations, soft-tissue injuries, and micropathological changes as revealed by MRI scans. It is imperative to differentiate SCIWORA from other potential conditions such as arteriovenous malformation, multiple sclerosis, acute transverse myelitis, acute disseminated encephalomyelitis, infarction, and intramedullary neoplasms during the diagnostic process. The severity of SCIs is currently categorized based on the ASIA grading system and MRI findings[39-41]. The ASIA grades are as follows:

i. Grade A: Complete loss of motor and sensory function below the injury site.

ii. Grade B: Sensory incomplete injury, where neither sensory nor motor function is maintained below the injury level or on either side of the body, and no motor function is preserved for more than three levels below the injury site.

iii. Grade C: Motor incomplete injury, characterized by preserved motor function below the injury level, with more than half of key muscle functions graded at <3 at a single level below the injury.

iv. Grade D: Motor incomplete injury, which is similar to grade C but involves a higher degree of preserved key muscle function, with muscle grades exceeding three.

v. Grade E: A return to normal function, where all sensory and motor function segments are classified as normal in a patient who previously exhibited deficits.

However, it is important to note that there are limitations in applying the ASIA classification system to young children, and accurately assessing the severity and ASIA grade of SCI in pediatric patients is difficult. Therefore, repeated assessments of neurological function are important. Moreover, a 72-h examination provides a more accurate prediction of outcomes in patients with

motor complete injuries (Grades A and B)[42]. The MRI features help to classify the severity of the injury, as they can reveal various conditions, including normal appearance, edema, hemorrhage, soft-tissue injury, or contusion[9]. Moreover, repetitive MRI examinations can reveal distinct pathological changes, even in cases where the initial MRI appears normal, which is attributed to the strength of the external forces. Notably, during the acute stage, diagnosing spinal shock can be challenging. Therefore, the utilization of DTI and diffusion tensor tractography (DTT) may provide a more accurate diagnosis[43].

6. Treatment

SCIWORA patients with complete neurological deficits often experience poor recovery in their neurological function. It is essential to consider the developmental changes that children undergo and to provide appropriate care as they mature. It is essential to consider the developmental changes that children undergo and to provide appropriate care as they mature. Treatment for SCIWORA varies according to the patient's MRI findings and ASIA grade[44]. Whether surgical or non-surgical, the primary objective remains the prevention of secondary injuries and the achievement of a favorable prognosis[45]. Surgery becomes necessary if the spine is unstable or if symptoms deteriorate during conservative treatment. The treatment approach for SCIWORA should be individualized, taking into account the unique circumstances of each case[46]. Treatment options for SCIWORA include immobilization, surgical decompression, pharmaceutical therapy, early rehabilitation, preventive measures, and post-treatment care[39,47-52].

6.1. Pre-hospital aid

Appropriate and accurate pre-hospital medical attention is critical in managing SCIWORA, as it significantly contributes to lowering mortality and improving overall patient prognosis. Achieving early diagnosis and developing more effective treatment strategies for SCIWORA necessitate the close collaboration of a multidisciplinary team of healthcare professionals[53]. Multiple medical teams, including emergency medical technicians, paramedics, orthopedic specialists, emergency physicians, neurosurgeons, general surgeons, intensive care unit personnel, radiologists, neurologists, and anesthesiologists, must work in concert to address the complex nature of SCIWORA cases[54]. Given the lack of precise scientific data supporting standardized treatment protocols, therapeutic decisions should be tailored to individual patient needs and should involve a multidisciplinary team of experts[55]. The implementation of transfer and pre-hospital care guidelines for SCIWORA is essential and should be universally adopted across all health-care facilities[56,57].

After a spinal cord injury, paramedic staff should promptly assess the patient's condition and immobilize the patient to prevent further movement of the head and the entire spine, thus reducing the risk of secondary injury[9,18,58-60]. Health-care teams must be cautious when obtaining the medical history of SCIWORA patients. Moreover, it is crucial to show care and attention during intra-hospital transfers within a single institution to minimize the risk of adverse events during the transfer procedure[61,62]. Effective communication between emergency services and the treatment facility is essential. Absolute cooperation between multiple disciplines not only safeguards the patient from further SCI but also expedites diagnosis and facilitates better treatment decisions[63-65].

6.2. Conservative treatment

Once the diagnosis of SCIWORA and the assessment of injury severity have been established, it is essential to monitor the patient's vital signs to ensure stability. Conservative treatment, characterized by the avoidance of surgery and reliance on non-operative treatments, is always the first choice, and surgical intervention is considered the last option. However, in emergency situations, surgical intervention may become necessary. Moreover, if symptoms worsen during conservative treatment and the patient's stability is compromised, alternative treatment options must be considered. Notably, some patients respond well to conservative treatment, achieving significant improvements[9,66,67]. Conversely, there are cases where conservative treatment does not yield any improvement[18,27,68].

6.3. Pharmaceutical therapy

Methylprednisolone (MP) therapy has shown potential for improvement and favorable clinical outcomes in some cases[13,32,69-71]. However, recent studies have reported poor prognoses associated with MP treatment[25,58,72-75]. Since 2013, the American Association of Neurosurgeons and the Congress of Neurological Surgeons guidelines no longer recommend the use of MP. In 2017, AOSpine recommended MP as a treatment option for patients within 8 h of acute SCI. Notably, in pediatric patients with acute SCI, high-dose MP administered within the first 8 h failed to show any advantages but showed an increase in incidences of pneumonia and other complications such as osteoporosis and femur head necrosis, especially in intensive care unit cases[76,77]. However, certain forms of SCIWORA (e.g., surfer's myelopathy and acute hyperextension SCI) result from ischemic insults to the spinal cord, and there is no place for the use of steroids or other drugs such as Ganglioside (GM), in the treatment of these patients.

Furthermore, there is a lack of evidence supporting the use of drugs in the treatment of SCIWORA in children.

6.3.1. Considerations for determining drug dosage

The determination of drug dosage should take into account the following criteria:

i. Age of the children
ii. If the child's age, weight, and vital signs are stable, ensure open communication with the child's family regarding the potential risks associated with the use of these drugs
iii. For intravenous (IV) drug therapy, consider factors such as infusion rate, body weight, dosage, initial IV dose, and maintenance infusion rate before administering MP
iv. To minimize the risk of complications, discontinue MP as soon as previous neurological issues have been resolved
v. Ideally, pharmaceutical therapy should commence within the first 8 h after the injury, but it can be considered up to 24 h post-injury[76,78]
vi. Contraindications for MP use include patients at risk of pneumonia, diabetes patients, those with gastrointestinal abnormalities, a time gap of more than 24 h since injury, complete SCI, open injuries associated with SCI, and cases where operative treatment is indicated.

6.4. Immobilization

Immobilization serves as the first step in the treatment of SCIWORA, with removal following injury stabilization[74]. Immediate immobilization at the accident scene should be maintained until a comprehensive assessment of the child can be conducted. The practice is essential for preventing further damage and risky activities[79,80]. External immobilization is recommended for a duration of up to 12 weeks. Moreover, early discontinuation is suggested for asymptomatic patients with confirmed spinal stability[81]. Early immobilization is associated with a favorable prognosis. However, cervical spine immobilization is complicated due to its intrinsic elastic characteristics. Furthermore, the inherent limitations of the cervical collar (allowing some degree of rotation leading to incomplete stability) and potential risks associated with the use of the halo vest (infection, pin loosening, and psychological effects) are all crucial points to consider[41]. The benefit of rigid immobilization is unproven in the case of strictly normal MRI[82].

6.4.1. Points to consider in immobilization following points

i. Initiate early immobilization, perform extrication, provide initial resuscitation, and arrange for evacuation to a trauma facility capable of diagnosing and treating the patient
ii. Maintain immobilization until the patient becomes asymptomatic
iii. Discontinue cervical immobilization if an MRI conducted within 48 h of injury reveals no pathological changes
iv. In cases associated with atlanto-occipital ligamentous injuries, consider recommending halo vest immobilization or occipitocervical stabilization and fusion.

6.5. Surgery

Non-operative treatment is always the first choice for SCIWORA, especially in cases of stable spine injuries. Surgical intervention becomes an option if conservative therapy fails or if the injury is unstable. However, in cases of progressive neurologic deterioration with or without spinal cord compartment syndrome or spinal cord intramedullary hypertension during conservative treatment, as well as in instances involving cord compression due to a hematoma, extruded disk, bony fragment, or unreduced dislocation, immediate surgical intervention is required to achieve a favorable recovery. Surgical intervention, when indicated in SCIWORA cases, has been shown to be safe and associated with significant positive outcomes, especially when performed promptly after the onset[47,49,75]. When the thoracolumbar injury classification and severity score (TLICS) is <3, conservative treatment is generally suitable. However, when the score reaches 4 points, the decision may lean toward operative or non-operative treatment. Moreover, the TLICS system provides guidance for surgical treatment decisions in patients with a TLICS score of 5 or higher[83,84].

6.5.1. Novel surgical approaches

Non-fusion laminectomy, followed by immobilization, has shown promise in significantly improving outcomes in children while reducing complications related to the growth scales[85]. However, it can have adverse effects on children's growth, potentially leading to spine misalignment and internal fixator loosening. Laminectomy is a procedure that can alleviate pressure on the spinal cord. However, minimizing muscle dissection and reducing the number of vertebrae involved in the laminectomy can enhance post-operative stability. In an effort to mitigate the complications associated with other treatment methods and achieve significant results, cerebrospinal fluid lumbar drainage has been considered as a potential treatment choice. It is essential to exercise caution when using this approach, and further clinical studies are required to establish its effectiveness[86].

6.6. Treatment decision

The treatment decision for SCIWORA in children is complex as it depends on various key factors, including:

i. Age of the child
ii. Severity of the injury
iii. Time of symptoms onset
iv. ASIA grade at the time of admission
v. Symptoms deterioration
vi. Patient stability and associated injuries
vii. Presence of deformity or other spine-affecting diseases
viii. MOI
ix. Number of affected segments
x. Presence of intradural, extradural, or both
xi. Appearance of edema, hematoma, or both.

6.7. Rehabilitation procedure

Rehabilitation techniques are designed to avoid secondary effects, promote neurological recovery, and improve motor function. Once injury stabilization has been achieved, the focus of rehabilitation shifts to preventing secondary complications. In SCI patients, it is crucial to consider the physical, neurological, emotional, and psychological changes that arise during childhood and early adolescence. This holistic approach, often referred to as the "medical home," is the most important and critical factor in the management of SCI[87]. The ultimate goals of recovery are as follows: (i) Strengthening everyday independent life practices; (ii) facilitating adaptation to a new way of life through recreational activities and household events; and (iii) supporting reintegration into the children's environment[88]. Home-based interventions during rehabilitation therapy have proven effective in promoting the development of motor functions[89,90]. Following a SCI, extensive practice, including over-ground practice, results in significant recovery[91]. In pediatric rehabilitation, numerous tools are available, but some present disadvantages, particularly in young children. Achieving optimal recovery can be challenging, as it often requires a significant amount of space for assessment. In addition, item-based tasks can be time-consuming, and certain trials may not be appropriate, especially for young children[92]. Initiating early rehabilitation training following the selected treatment method can help reduce the incidence of pressure sores, deep vein thrombosis (DVT), and other complications. This approach can also lead to a better prognosis and improved outcomes[93]. Spasticity following SCI is a motor disorder characterized by increased muscle tone with exaggerated tendon jerks. Some medications, such as tizanidine, can cause hypotension and bradycardia, while *Clostridium botulinum* works as a neuromuscular blocker. If the patient does not exhibit any changes, it is important to consider the secondary complications of SCI, such as DVT, fractures, gastric ulcers, heterotopic ossification, or syringomyelia. To prevent these complications, it is advisable to use the lowest spasticity medication that is effective, ensure the patient stays warm, and be mindful of cold weather conditions[15,94].

6.8. Complications of SCI in children

Complications resulting from SCI in younger children differ from those in adolescents and adults, necessitating early prevention and intervention. Among younger children with SCI, 96% developed scoliosis, 57% had hip dysplasia, and 7% exhibited a latex allergy. In cases where injuries were at or above the T6 level, 34% experienced autonomic dysreflexia, 41% developed pressure ulcers, and 61% suffered from spasticity, particularly in the absence of bowel or bladder control. Notably, 82% were on intermittent catheterization, and 69% were on a bowel program. Additional complications include hyperhidrosis, kidney stones, ambulation, wheelchair dependence, lifelong growth and developmental issues, and various secondary complications, such as decreased bone density, increased risk of fracture, muscle atrophy, and cardiovascular impairments, all of which may arise from SCI[29]. Complications such as pulmonary compromise, pneumonia, urinary tract infection, gastrointestinal bleeding secondary to stress ulcers, DVT, decubitus ulcers, and even the risk of death pose significant challenges in the treatment of children with thoracic and lumbar spinal cord lesions[95]. Preventing DVT is helpful in reducing patient mortality and the risk of pulmonary embolisms. Moreover, the early elevation of the patient's head of the bed is essential to prevent various respiratory-related complications. These complications should be viewed as risks of SCI, emphasizing the need for early prevention and intervention throughout the rehabilitation process.

6.9. Traditional Chinese medicine (TCM)

TCM is an important supplementary treatment in potentially repairing injured spinal cords. Early implementation of TCM therapy has demonstrated effectiveness in improving motor function in SCI patients[96]. Six active natural compounds found in herbs commonly used in TCM exhibit anti-inflammatory and antioxidant properties. These compounds have been shown to significantly reduce bleeding, edema, and necrotic tissue in the damaged area[97]. Consequently, TCM can serve as an auxiliary therapy to promote functional recovery following SCI[98].

6.10. Post-treatment suggestions

Delays in symptom presentation and the potential for recurrence pose significant risks in SCIWORA cases, and nursing management should be vigilant in this regard[99]. To

mitigate the risk of disease recurrence, patients are advised to avoid physical activities during the first 6 months post-treatment[81,100]. In cases of asymptomatic craniocervical arterial dissection, the use of aspirin, clopidogrel, or other antithrombotic agent for 3 to 6 months is recommended as first-line therapy. Furthermore, if symptoms progress, consideration may be given to anticoagulation therapy (using low-molecular-weight heparin or warfarin). It is important to note that these medical therapies carry an increased risk of hemorrhage[39]. In addition, conducting post-operative CT and MRI on the 2nd day following treatment can help assess treatment complications, monitor the patient's progress, and evaluate the stability of the injury[101].

7. Prognosis

Differences in the MOI present significant challenges in the diagnosis, treatment, and prognosis of SCIWORA. SCIWORA can be devastating. According to the previous reports, early improvement within the first 24 – 72 h of presentation has been observed in some patients. Children who experience minor trauma, have incomplete injuries, or remain stable throughout treatment can achieve full recovery. In contrast, the prognosis for patients with complete injuries, instability, or worsening symptoms depends on factors such as the treatment method, treatment time, and the severity of injury. Moreover, the presence of spinal cord disruption or major hemorrhage on MRI in cases of severe neurologic deficit is associated with a poor prognosis. Conversely, mild SCIWORA (spinal cord concussion) usually results in full recovery, and a normal MRI appearance is indicative of a favorable prognosis[81]. The use of DTI and DTT to categorize SCI can help in determining the severity, prognosis, and optimizing diagnosis by detecting microscopic pathological changes in the WM[34,43,93]. The prognosis in cases of SCIWORA depends on the child's age, injury location, neurological examination findings, detected MRI abnormalities, and classification based on DTI-DTT.

8. Prevention

Given the rarity and complexity of SCIWORA cases, where multiple treatment attempts often fail to control the condition, it becomes imperative to address the underlying causes. Public awareness, especially among individuals and their families, is crucial, particularly for children under the age of 8 who may exhibit warning signs. Those engaged in activities involving prolonged and repeated spinal hyperextension, such as dance instructors, should take measures to minimize this risk. Parents should avoid actions that could potentially harm their child's spine, such as shaking the baby or rough handling. It is essential for everyone to be well-informed about how to respond in case a child experiences SCIWORA symptoms. In addition, health-care professionals should be vigilant, as some SCIWORA cases may present with normal initial MRI scans.

9. Conclusion

SCIWORA is frequently diagnosed in children aged ≤8 years old, and the unique characteristics of the pediatric spinal cord play a critical role in this condition. Various MOIs can result in SCI or ischemia. The objective of this guideline is to provide a comprehensive framework and treatment approach for addressing SCIWORA in children. Moving forward, effective treatments should be developed through multidisciplinary collaboration and supported by robust evidence-based medicines. As new treatment measures continue to evolve to improve the quality of life for children with SCIWORA, this guideline will undergo further revisions and improvements.

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Conflict of interest

All the authors declare no conflicts of interest.

Author contributions

Conceptualization: Ruba Altahla, Xu Tao
Writing – original draft: Ruba Altahla, Jamal Alshorman
Writing – review & editing: Jamal Alshorman

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