Spinal Concussion in Adults: Transient Neuropraxia of Spinal Cord Exposed to Vertical Forces

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OBJECTIVE: **The aim of the study is to discuss along with literature knowledge the post-traumatic clinical progression of cases with symptoms of transient spinal cord impact and cases of spinal concussion following exposure of the vertebral column to vertical forces.**

MATERIALS AND METHODS: **A total of 43 cases, all falls from height, were diagnosed with spinal concussion. It was determined that the vertebral column had been exposed to the effects of vertical forces, and the spinal cord had been affected by vertical forces. In all cases, spinal magnetic resonance imaging and dynamic X-ray examinations were performed at the time of admission. Clinical symptoms of the cases were recorded by scoring based on the Torg Grading System.**

RESULTS: **Cases were started on conservative treatment because radiologic symptoms that would explain the clinical symptoms could not be detected. Most frequently encountered were the neurologic symptoms related to the upper thoracic and lower cervical segments being affected. In 7 cases, urinary incontinence was also detected. Symptoms related to the spinal cord being affected were completely recovered in 1–3 days in all cases.**

CONCLUSION: **As a result of the vertebral column being affected by vertical forces, the most frequently affected are the thoracic segments of the spinal cord. These cases show similarities to real spinal cord injury without radiographic abnormality cases when evaluated along with clinical and radiologic symptoms. Absolute differential diagnosis from real spinal cord injury without radiographic abnormality cases cannot be made until total neurologic recovery takes place.**

INTRODUCTION

Spinal concussion (SC) was first described by Torg et al. in 1986 as a transient quadriparesis occurring following neuropathy of the cervical cord. Findings are usually described as sensory and motor deficits that improve within the first 15 minutes but can last up to 48 hours.[1] Calcium transport irregularities due to transient impairment of membrane permeability in the spinal cord are thought to be responsible for the pathophysiology of this condition.[2]

This condition most frequently follows the exposure of the cervical cord to trauma during sports activities in football players.[1] It has been reported that there was a serious reduction in the rate of incidence when precautions were taken against trauma and protective gear was used.[3]

SC is similar to spinal cord injury without radiographic abnormality (SCIWORA) syndrome as pathology affecting the cord cannot be demonstrated radiologically. However, differential diagnosis must be made because the neurologic deficits that develop in SCIWORA do not fully recover. Since the symptoms resolve within the first 3 days at the latest in SC, a definitive diagnosis can be made after the third day in spinal trauma cases that demonstrate clinical findings up to the third day.

This study aims to discuss the mechanism underlying the picture of spinal concussion that arises from the spine being impacted by vertical forces, along with knowledge of neuroanatomy and clinical findings. Furthermore, it aims to be instructive in reaching a differential diagnosis from SCIWORA and

Key words
- Neurologic deficit
- SCIWORA
- Spinal concussion
- Spinal cord injury
- Transient neurapraxia

Abbreviations and Acronyms
MRI: Magnetic resonance imaging
SC: Spinal concussion
SCIWORA: Spinal cord injury without radiographic abnormality

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real SCIWORA, which show similarities when evaluated in the presence of clinical and radiologic findings.

MATERIALS AND METHODS

Forty-three cases that had been diagnosed with SC and had been followed up between the years 2013 and 2017 were evaluated retrospectively. On the basis of the obtained neurologic findings, MRI examination was performed in all cases in the early period following trauma. The diagnosis was also corroborated by dynamic x-ray images that were taken to assess a potential instability. The durations of the neurologic deficits were sorted according to the grading system of Torg et al.[4] According to this system, the following definitions were used: "plegia" for episodes with complete paralysis, "paresis" for episodes with motor weakness, and "paresthesia" for episodes that involve only sensory changes without any motor involvement. An incontinence criterion was also added to this system (Table 1).

Radiologic Evaluation

All cases were evaluated as high-energy multitrauma cases, and spinal computed tomography scans were performed as the first radiologic examination at the time of admission. Anterior-posterior and lateral flexion-extension radiographs of all cases were taken, and MRI scans of the spinal cord segment associated with the neurologic deficit were performed. Radiology reports were prepared by independent neuroradiologists who were not informed about the clinical statuses of the patients.

RESULTS

Thirty-one of 43 cases were agricultural workers who were examined due to falling out of trees, and 12 cases were followed up for neurologic deficits that appeared after falling from multistory apartments or due to heavy manual labor. The average age of the cases was 33.2 (range 26–57 years). SC was diagnosed in 36 male and 7 female cases. Urinary incontinence before the time of admission was determined in 7 cases, and anal incontinence was identified in 1 case. Motor and sensory examinations of the cases were evaluated, and segmental asymmetries encompassing 1–3 levels were detected in 24 cases (Table 2). In 3 cases, transient paraplegia was identified in the early period. In other cases, the motor deficit was determined as paralysis at variable levels.

MRI examination was performed in the early period as part of the radiologic examinations, and a pathologic formation that could support the neurologic findings or cause cord injury was not detected. Dynamic x-ray images of all cases were also taken, and no instability was encountered. End-plate fractures from the acute process were detected in the vertebral body in MRI and x-ray examinations of 11 patients; however, these did not match the degree of neurologic findings. These cases were followed up with corsets. Cervical lamina fracture was detected in 1 case, and symptoms of neuropraxia that appeared to correspond to the upper thoracic segments were encountered.

It was found that the neurologic findings associated with SC frequently caused defects in the thoracic (27 cases) and cervical (16 cases) regions, which did not reinforce the series existing in the literature who were defined after sports injuries. High-dose methylprednisolone treatment was initiated in 7 cases where motor deficit recovery did not occur in the first few hours.

DISCUSSION

It has been demonstrated by our study that the upper thoracic and lower cervical segments were frequently affected as a result of the spine being impacted by vertical forces following falls from height. It has been shown in previous studies that SC most frequently affected the cervical segments. This was explained by the cervical segments being the most active section and therefore would be affected by more numerous and various mechanisms following trauma.

SC that is defined as cord neuropraxia is a clinical picture encountered after spinal trauma and is rarely diagnosed. SC, which is mostly encountered in athletes, is often presented with clinical symptoms associated with the exposure of the cervical region. This is thought to be because this region is more mobile and more vulnerable to trauma than other parts of the spine.[5] Previous studies in the literature relate SC to the spinal cord being affected by the flexion-extension forces following sports injuries or car accidents. It is known that the flexion-extension forces most frequently affect the cervical segments of the spinal cord.

In this clinical picture, sensory and motor manifestations may appear at the same time, and clinical findings totally resolve within minutes or a few days. Although the radiologic examinations do not portray any findings showing that the cord is affected, motor and/or sensory effects are observed in the bilateral extremities.[6-8]

SC cases are clinically similar to SCIWORA cases. Cases of both groups manifest neurologic findings associated with the affected spinal cord, and both fail to present radiologic findings demonstrating cord injury. In the literature, it has also been defined as SCIWORA when no effects can be observed in the vertebral column in SCIWORA cases, but the cord injury is detectable with MRI. For this reason, for the first time, Yucesoy et al[9,10] described

Table 1. Neurologic Deficit Types and Onset of Symptoms

	<1 Hour	1–12 Hours	12–24 Hours	24–72 Hours
Paresthesia number = 23	5	11	5	2
Paresis number = 17	2	10	3	2
Plegia number = 3	0	2	1	0
Incontinence number = 7	4	3	0	0

Table 2. Segmental Differences of Neurologic Deficits by Region

Affected Region	Segmentary Asymmetry on Deficits	Levels of Asymmetry
Lower cervical (n = 16)	Asymmetric: 11	2 segments: 5
	Symmetric: 5	1 segment: 6
Upper thoracal (n = 18)	Asymmetric: 9	2 segments: 4
	Symmetric: 9	1 segment: 5
Midthoracal (n = 6)	Asymmetric: 2	2 segments: 1
	Symmetric: 4	1 segment: 1
Lower thoracal (n = 3)	Asymmetric: 2	2 segments: 0
	Symmetric: 1	1 segment: 2

cases in which cord injury could not be detected even on MRI under the real SCIWORA title.

Concerning loss of motor and sensory functions in SC and SCIWORA cases, it is not exactly clear which tracts are affected. Clinical findings indicate that the lateral corticospinal and lateral spinothalamic tracts are more predominantly affected. Probably, the exposure of other tracts could not be clearly revealed with clinical findings, or it is masked by findings associated with these 2 tracts. Although there is a segment where the cord is affected more dominantly, the fact that the detected deficits are asymmetric indicated that the adjacent segments are also affected (Figure 1).

Clinical findings that show recovery are the improvement of sphincter function, motor deficit, and sensory deficit, respectively. The reason why it is rarely diagnosed is probably because the minor deficits that occur during trauma heal in a short time, and therefore further examinations are not carried out, preventing a diagnosis from being made. The cases in which rapid clinical improvement is seen may also be overlooked by being evaluated as temporary somatization disorder or conversion.

It has been argued that the cervical region is frequently affected by spinal trauma because it is more vulnerable to trauma as the cervical cord is more mobile than the other regions.[11-15] It has been suggested that in the pediatric age group, the cervical region is affected by trauma more frequently because the paraspinal muscles have not completely developed. However, the easier fracture or dislocation of the vertebrae following traumas in this region may be due to the fact that the vertebrae in the cervical column are relatively smaller and thinner. The fact that the cervical region demonstrates a greater degree of flexion and extension following trauma than the other regions also makes the trauma pattern in this region varied. The more mobile cervical region is affected more frequently by traumas that affect the anterior-posterior axis of the spine such as traffic accidents and sports injuries, which are more commonly encountered. In the literature, SC and SCIWORA have often been associated with cervical column exposure.

Although SC and SCIWORA present common features at the time of diagnosis, there are also differences. The similarities and differences between SC and SCIWORA that may aid in reaching a differential diagnosis have been presented in Table 3. When differences between the 2 groups and their subgroups are presented, it must be considered that there may not be absolute sharp boundaries between the groups.

The intumescentia cervicalis being located in the cervicothoracic junction and possessing the largest surface area and volume vulnerable to trauma may cause the deficits associated with this region to appear more frequently after the spinal column is affected by vertical forces in SC cases.

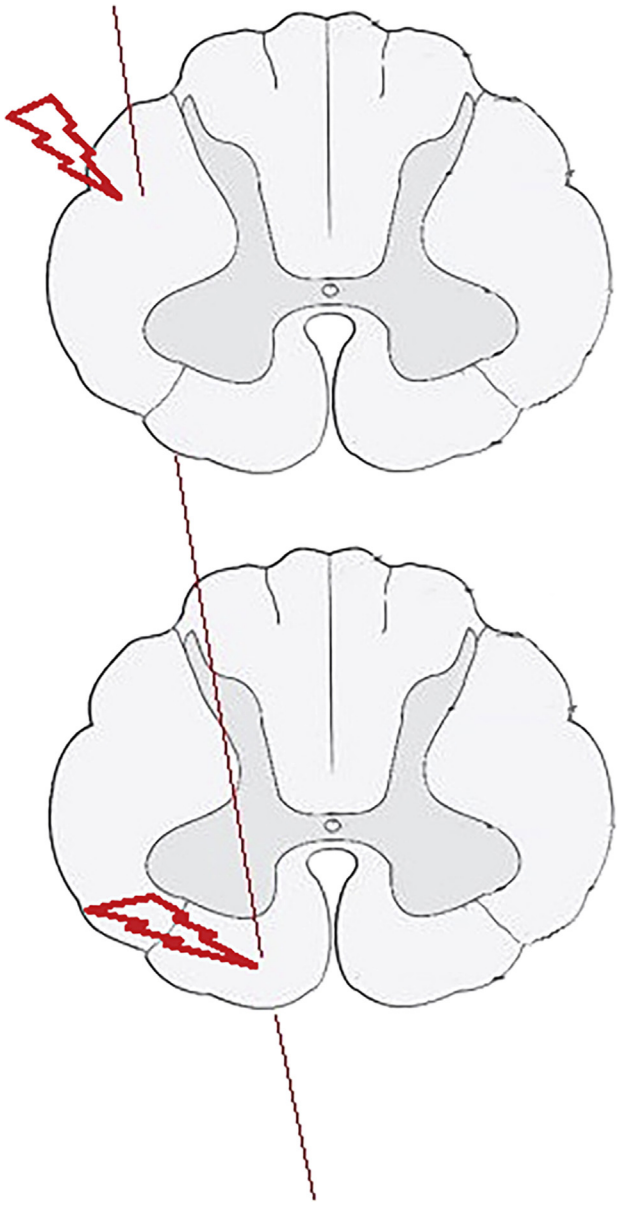

Figure 1. Vertical forces other than 90 degrees may cause asymmetric tractus injury.

Table 3. Differential Diagnosis Criteria Between SCIWORA and Spinal Concussion Cases

	SCIWORA	Real SCIWORA	Spinal Concussion (Affected by Axial Forces)	Spinal Concussion (Affected by Vertical Forces)
Spinal cord injury on MRI	Yes	No	No	No
Spinal column injury	No	No	Maybe*	Maybe*
Permanent neurologic deficit	Yes	Yes	No	No
Complete neurologic recovery	No	No	Yes	Yes
Symmetric neurologic deficit	Usually Yes	Usually Yes	Usually Yes	Usually No
Absolute boundaries of spinal cord injury or impact	Yes	Yes	Yes	No
Segment where most frequently encountered	Cervical	Cervical	Cervical	Thoracal
Type of injury	Usually flexion-extension	Usually flexion-extension	Usually flexion-extension	Superior-inferior or oblique
Course of Recovery	If there is any healing, after 2–3 days	If there is any healing, after 2–3 days	Within the first 3 days	Within the first 3 days

SCIWRA, spinal cord injury without radiographic abnormality; MRI, magnetic resonance imaging.
*Spinal column injury is not related to spinal cord injury.

Concerning the results obtained in our study, 43 cases with a diagnosis of SC were followed up. When the way of life in the region was taken into account, the great majority of the evaluated cases were determined to be agricultural workers who fell from height, resulting in their spines being affected by vertical forces. While findings of cervical cord exposure were detected in 16 cases, it was demonstrated that the spinal cord was affected in the thoracic region in 27 cases.

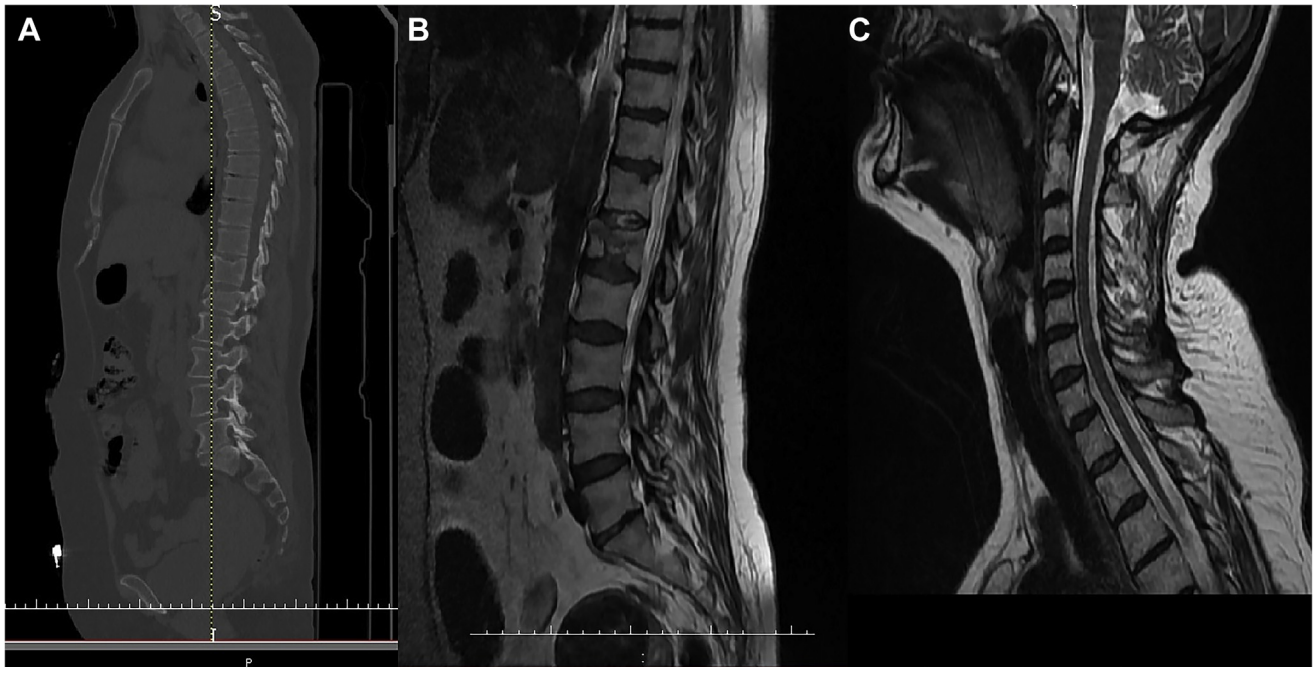

Figure 2. (**A**) Sagittal reconstructed computed tomography shows L1 vertebral body fracture caused the cervical spinal concussion. (**B**) Sagittal T2-weighted magnetic resonance imaging (MRI) of the lumbar region shows L1 body fracture without cord injury. (**C**) Sagittal T2-weighted MRI of the cervical region without cervical cord injury but with the cervical spinal concussion due to L1 body fracture.

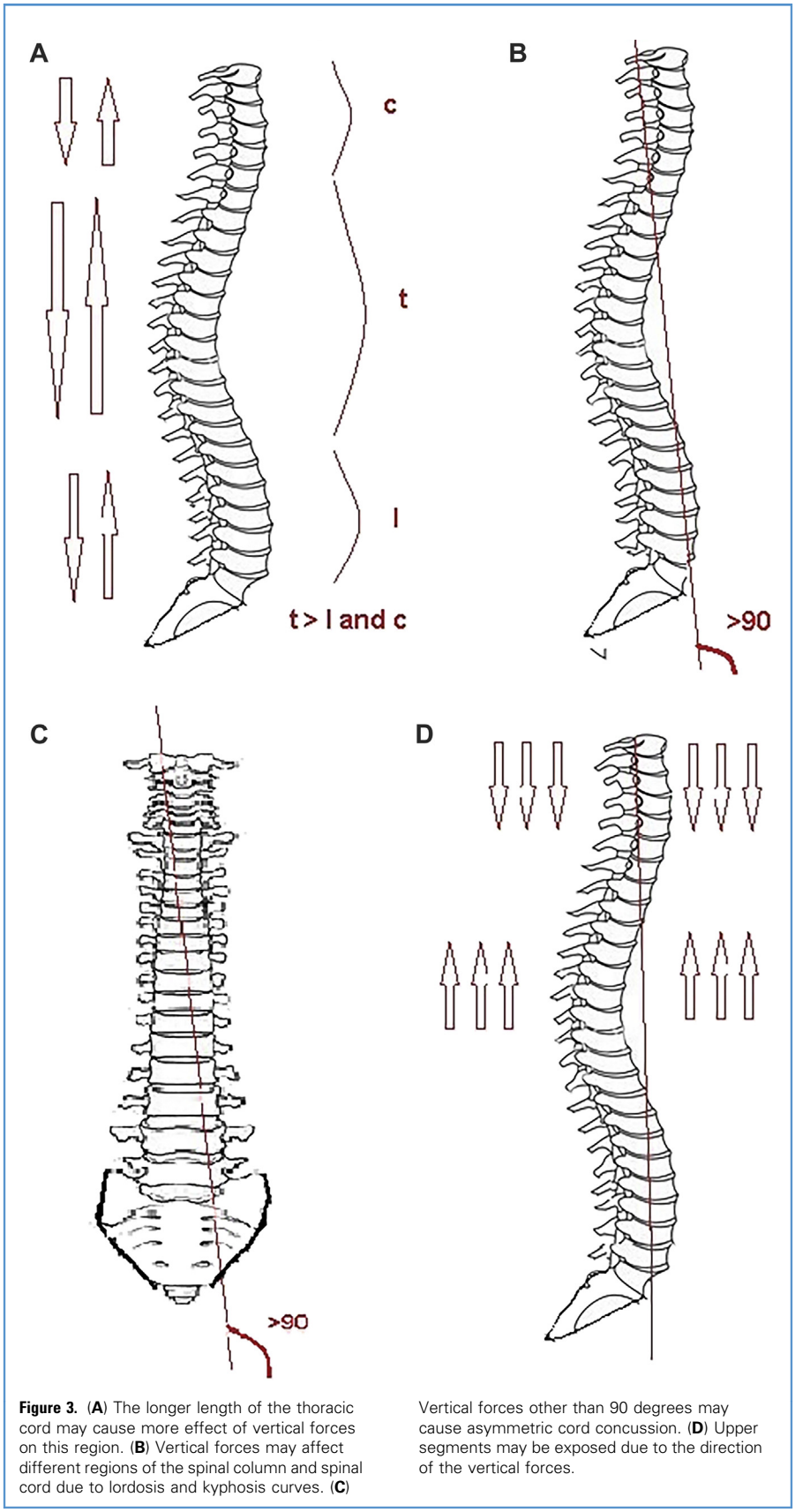

Figure 3. (**A**) The longer length of the thoracic cord may cause more effect of vertical forces on this region. (**B**) Vertical forces may affect different regions of the spinal column and spinal cord due to lordosis and kyphosis curves. (**C**) Vertical forces other than 90 degrees may cause asymmetric cord concussion. (**D**) Upper segments may be exposed due to the direction of the vertical forces.

It was considered that, under the vertical forces, the flexibility of the spine was augmented in the cervical region by the fact that the lordosis curve in the cervical region is greater than the kyphosis curve in the thoracic region. Thoracic or lumbar vertebral end plate fracture was detected in 11 cases, but it was determined that the neurologic findings started more than 2–3 segments above the level of the fracture (Figure 2).

The spinal cord being affected by vertical forces after a fall from height causes the column to be subjected to the effects of compression from the top and bottom. Due to the longer length of the thoracic cord, it is expected to be exposed more to the effects of vertical forces (Figure 3A). In the case where no anatomic structures exert pressure on the cord, the cord will be affected in the form of superior and inferior compression. If no cord injury developed in cases with isolated vertebral fractures, the region where the cord had been directly affected was determined to be the segment 1–2 levels above the level where the spine had been exposed, due to thoracic kyphosis. Injuries like spinal cord compression with vertical forces may also arise from the cord coming into collision with the posterior of the vertebral body 1–2 segments below.

The spinal cord falling under the effect of axial forces that would bring about flexion-extension affects a single segment of the cord. However, in cases of fall from height, the spinal cord is affected by oblique forces unless the fall occurred at exactly 90 degrees. In this case, the spinal cord is exposed to 2 forces in different directions. The cord falling under the effect of oblique forces explains the segmental asymmetry in the neurologic findings. Due to the neighboring segments being exposed to forces in different directions, different tracts are affected in neighboring segments, and as a result, neurologic findings associated with different tracts may appear in neighboring segments (Figure 3). Moreover, lordotic and kyphotic curves of the spinal cord cause it to be affected in different directions in different segments rather than the cord falling under the effect of vertical forces along its length.

As a result, the vertical forces to which the spinal column is subjected may affect not only a single segment but also the neighboring upper segments because of the curvature that thoracic kyphosis forms in the cord. For this reason, functional losses indicating that the cord is affected may appear asymmetrically. Additionally, this idea can explain asymmetric deficits if the vertical forces are not at 90 degrees (Figure 3B and C).

In theory, following the spine being affected by vertical forces, these forces are expected to converge most frequently in the center of the thoracic region. However, clinical findings often belong to the upper thoracic or lower cervical segments since the vertical forces to which the midthoracic region is subjected may also affect the upper segments of the cord (Figure 3D).

CONCLUSIONS

SC, which occurs after the spinal column is affected by vertical forces, most frequently affects the upper thoracic and lower cervical segments. Neurologic symptoms may be asymmetric and may extend to adjacent segments on the opposite side. Differential diagnosis should be made from real SCIWORA on the basis of clinical and radiologic findings.

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