Long Term Follow-Up Results of Spinal Concussion Cases: Definition of Late Injuries of the Spinal Cord

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■ OBJECTIVE: **This study aims to evaluate the long-term clinical and radiologic findings of cases diagnosed with spinal concussion and to describe the spinal cord injuries that are detected in the later course.**

■ METHODS: **Data obtained from 91 cases, who had been diagnosed with spinal concussion, were retrospectively evaluated. These were placed in 2 groups according to the type of trauma (axial forces or vertical forces). Magnetic resonance imaging scans taken >6 months after the trauma were inspected.**

■ RESULTS: **Axial and vertical forces result in different types of spine injuries. The effect of vertical forces on the spinal cord can involve longer segments and the effect of axial forces remains limited to a few segments. Vertical forces usually result in the development of syringomyelias in the late period, whereas axial forces may cause cavitation and stretch injuries to the spinal cord.**

■ CONCLUSIONS: **Although patients with spinal concussion manifest complete recovery in the early period after the trauma, findings related to the spinal cord may appear in the later course. The direction of the forces that the spinal cord is subjected to may result in different cord injuries in the late period.**

INTRODUCTION

Described as spinal cord neuropraxia, spinal concussion was first identified by Torg et al[1] in football players. In this clinical picture that follows axial trauma, neurological function loss that originates from the spinal cord lasts between 15 minutes and 3 days, with neurological functions demonstrating complete recovery after this period.[2-5] In 2018, Asan[6] showed that spinal concussion could appear after the spine was subjected to high energy vertical forces. It was reported that this picture usually appeared due to falling from a height, which was mostly encountered in agricultural workers who fell off trees, and that neurological deficits that originated from the spinal cord could incorporate asymmetrical findings.

Because spinal magnetic resonance imaging (MRI) scans taken immediately after trauma do not show cord injury, these scans show similarities to cases of real spinal cord injury without radiologic abnormality (SCIWORA), where the cord injury cannot be demonstrated radiologically. However, as the neurological deficits in real SCIWORA do not recover, even after the third day, differential diagnosis between spinal concussion and real SCIWORA can be made in the early period.[6,7] On the other hand, patients with spinal concussion can be discerned from those with spinal shock, as the latter demonstrates sympathetic activity impairment, often presents radiologic evidence of spinal cord injury, and manifests a more severe clinical picture.

In the present study, long-term clinical and radiologic findings of cases diagnosed with spinal concussion were evaluated and the results were discussed.

METHODS

A total of 91 cases who had been diagnosed with spinal concussion between the years 2013 and 2018 were evaluated. The demographic distribution of the cases is presented in **Table 1**. Clinical findings at initial diagnosis and in the late period are presented in **Table 2**. The cases were evaluated in 2 groups based on the type of trauma. Group 1 patients were subjected to vertical forces and Group 2 patients were subjected to axial forces. Spinal MRI scans taken

Key words
- SCIWORA
- Spinal concussion
- Spinal cord injury
- Spinal cord neuropraxia
- Spinal trauma
- Syringomyelia

Abbreviations and Acronyms
MRI: Magnetic resonance imaging
SCIWORA: Spinal cord injury without radiologic abnormality

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Table 1. Demographic Distribution of the Cases

	Group 1 (vertical forces) (n = 58)	Group 2 (axial forces) (n = 33)	Total (n = 91)
Mean age (years)	32.57 ± 10.07 (16–62)	38.27 ± 14.06 (16–66)	34.64 ± 11.92 (16–66)
Etiology (*n* of cases)	Fall from height: 58	Car accident: 24 Fall from height*: 7 Violence: 2	Fall from height: 65 Car accident: 24 Violence: 2
Spinal concussion segment	Cervical: 14 (24.14%) Thoracic: 44 (75.86%)	Cervical: 26 (78.8%) Thoracic: 7 (21.2%)	Cervical: 40 (43.96%) Thoracic: 51 (56.04%)
Mean MRI follow-up (time and range, months)	22.69 ± 10.30 (7–52)	21.06 ± 11.54 (6–52)	22.09 ± 10.73 (6–52)
Late period MRI findings	Syringomyelia: 7 (12.06%) Cavity: 2 (3.45%)	Syringomyelia: 2 (6.07%) Cavity: 3 (9.09%)	Syringomyelia: 9 (9.89%) Cavity: 5 (5.49%)
Pathology segment	Cervical: 1 (1.72%) Cervicothoracic: 2 (3.45%) Thoracic: 6 (1.034%)	Cervical: 2 (6.06%) Cervicothoracic: 1 (3.03%) Thoracic: 2 (6.06%)	Cervical: 3 (3.30%) Cervicothoracic: 3 (3.30%) Thoracic: 8 (8.79%)
Total	15.52%	15.15%	15.38%

MRI, magnetic resonance imaging.
*Cases who fell backward from a height were evaluated as axial trauma cases.

at least 6 months after the trauma were evaluated and the results were compared across the 2 groups.

None of the cases had cord injury detected radiologically at the time of admission and all were followed-up with a diagnosis of spinal concussion after their clinical and radiologic examinations. Within the first 3 days the cases manifested complete recovery of the neurological deficits present at admission. None of the cases underwent surgical intervention. Cases who had motor deficits detected at the time of admission were administered methylprednisolone therapy at a loading dose. No specific medications related to the diagnosis of spinal concussion were administered during follow-up.

Dynamic x-ray examinations did not present findings of instability. Because these were multitrauma cases who had been subjected to high-energy trauma, cervical, thoracic, and abdominal computed tomography scans were evaluated as the primary diagnostic tool to reveal pathologies associated with other systems and to allow an early diagnosis in case of spinal fractures. Individuals who presented with compressive cord injuries due to fractures were excluded from the study. Cases with noncompressive cord injuries whose neurological deficits persisted were diagnosed with SCIWORA or real SCIWORA after their MRI examinations and excluded from the study.

Table 2. Clinical Findings of the Cases at Initial Diagnosis and in the Late Period

	Deficits at Initial Diagnosis	Deficits in the Late Period
Clinical findings	Motor deficits: 11 (12.1%) Sensory deficits: 88 (96.7%) Incontinence: 4 (4.,4%)	Motor deficits: 1 (1.1%) Paresthesia: 36 (39.6%) Radicular pain: 2 (2.,2%) Spinal pain: 3 (3.3%)

All cases were examined with MRI focusing on the segments diagnosed with spinal concussion. In the presence of multiple MRI scans, only the most recent scan was taken into account. Mean time of late MRI scans was calculated as 21.47 ± 11,02 months after the trauma (range, 6–52 months).

Statistical Analyses

The obtained data were recorded on an Excel (Microsoft Office Excel 2003, Washington, USA) file and organized into a database. Cross-group evaluations were performed using the independent samples t-test and Fisher's exact test with SPSS 20.0 (Statistical Package for the Social Sciences, Chicago, Illinois, USA). A P value <0.05 was considered statistically significant.

Ethics committee approval was obtained from Ahi Evran University Clinical Research Ethics Committee on 24 April 2018; no:2018-08/83.

RESULTS

A total of 91 cases were evaluated in the study, of which 59 were male and 32 female individuals. Mean age was calculated as 34.63 ± 11.91. Group 1 (58 cases) sustained vertical traumas; 14 cases were evaluated in the cervical spinal concussion subgroup and 44 cases in the thoracic spinal concussion subgroup. In total, 33 cases were evaluated in group 2; 26 cases were evaluated in the cervical spinal concussion subgroup and 7 cases in the thoracic spinal concussion subgroup. The comparison of the 2 groups, based on the type of trauma, revealed that thoracic concussions were more common in group 1, whereas cervical concussions were more common in group 2 ($P = 0.024$). MRI scans of group 1 cases taken in the late period (22.69 ± 10.30 months; range, 7–52 months) after the trauma revealed 7 cases with syringomyelias and 2 with cavitations. In group 2, 2 cases presented with syringomyelias and 3 cases presented with cavitations in the late period (22.09 ± 10.73 months; range, 6–52 months). The comparison of the 2 groups revealed that the prevalence of syringomyelia was higher in group 1 than in group 2 and this difference was determined to be statistically significant ($P = 0.004$). Pathologic findings in the late period, which radiologically corroborated spinal cord injury, were apparent in 14 cases (15.38%). The late MRI scans were evaluated to investigate whether the trauma type could be detected radiologically. No significant differences were found between the 2 groups. It was determined that syringomyelias appeared more commonly in patients with spinal concussion whose spines were subjected to vertical forces (**Figure 1**). Axial trauma, on the other hand, may result in cavitations or stretch injuries (**Figure 2**).

Among the 91 cases, 11 manifested transient episodes of paresthesia (mean, 4.7 months), and partial recovery was achieved by pregabalin treatment. Cervical protrusions with foraminal extension, which did not cause spinal cord compression, were detected in connection to the radicular pain. This occurred in 2 cases in whom the radicular pain responded to medication.

DISCUSSION

Cases of spinal concussion, which is defined as spinal cord neuropraxia, are rarely encountered.[8] The fact that the symptoms and neurological deficits experienced by the cases, who show complete recovery in a short time, makes its diagnosis difficult. No pathologic findings can be detected radiologically, further hampering diagnosis.[8] In addition, complete recovery of the symptoms by the time of diagnosis obviates the apparent necessity for further testing.[6] Because no pathologic findings are detected in radiologic tests performed for the initial diagnosis and that the symptoms recover during this time period may give the impression that the individual is experiencing conversion disorder.[6] As these are usually multitrauma cases, the absence of pathologic findings related to the spine and the spinal cord in the early tests allows investigations of other system pathologies that may require urgent care, further delaying diagnosis.[6] Therefore, spinal concussions are diagnosed based on clinical findings rather than radiologically.

The absence of a radiologic diagnosis, despite existing clinical findings, results in similarities to real SCIWORA cases. Although in SCIWORA cases, spinal cord injuries can be demonstrated on MRI scans, in real SCIWORA cases, which were defined in the later years, cord injuries also cannot be demonstrated using MRI, further complicating the diagnosis.[6,7,9,10] Neurological findings in spinal concussion recover in 15 minutes to 3 days. This condition allows differential diagnosis from real SCIWORA to be made. Hence, initially a differential diagnosis cannot be made between spinal concussion and real SCIWORA cases as neurological deficits last up to the third day. Therefore, these patients cannot receive a definitive diagnosis during the first 3 days and they must be considered as potential spinal concussion or real SCIWORA cases.[6,7]

Years after the initial description of spinal concussion due to exposure of the spine to axial trauma, it was stated that a picture of spinal concussion could also emerge after sustaining vertical forces.[6] Although axial traumas usually result in spinal concussions in the cervical region, which is more mobile,[8,11-14] vertical traumas can cause concussions to appear more frequently in the thoracic region, which comprises the longest segment of the spine.[6] Axial trauma brings about a flexion-extension motion in the spine, whereas vertical trauma usually affects the entire length of the spine and the spinal cord. In cases where the spine is not subjected to vertical forces at a right angle, the involved levels of the cord may present segmental differences, and therefore, the affected segments may be asymmetrical at the upper and lower levels, potentially resulting in transient asymmetrical deficits.[6] On the other hand, as the effects of axial forces on the cord are limited to a flexion-extension motion of the spine, significant segmental differences may not be present, and therefore, the neurological deficits that may appear are usually expected to be symmetrical.[6]

In the present study, cases who were diagnosed with spinal concussion after the exposure of the cord to axial or vertical forces

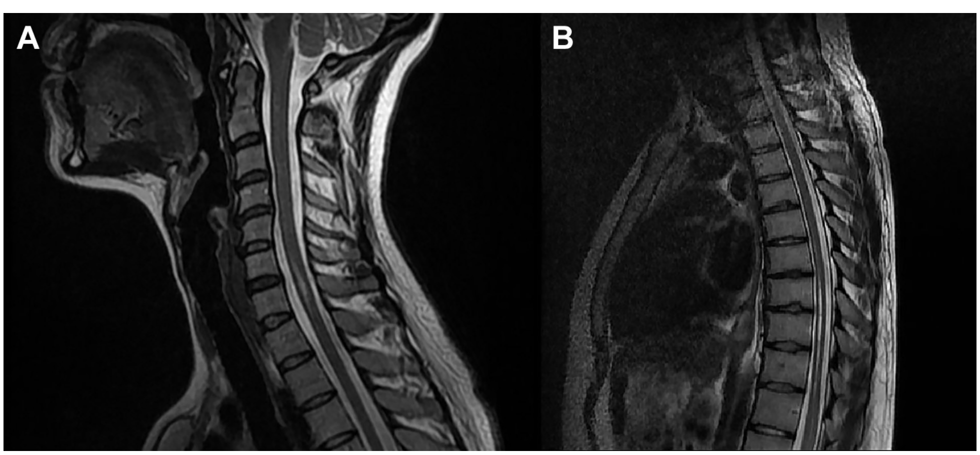

Figure 1. The magnetic resonance imaging scans show that post-traumatic syringomyelias in the thoracic region encompassed longer segments compared with those in the cervical region (**A, B**).

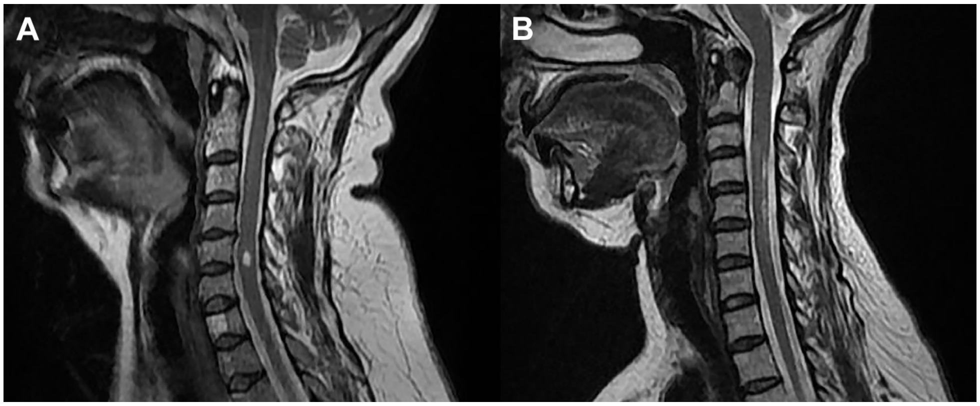

Figure 2. The late-term post-traumatic cavitary injury that appeared in the C3-4 region of the cord can be seen (**A**) in the sagittal section magnetic resonance imaging (MRI) scan. Late-term stretch injury in the posterior region of the spinal cord at C4-5 levels is demonstrated by sagittal section MRI (**B**).

underwent MRI scans in the late period. Although syringomyelias were detected more frequently in cases subjected to vertical forces, cavitations and stretch injuries in the late term were more common in cases subjected to axial forces (Figures 3A, B, and 4). Correlations are drawn between the type of trauma and late radiologic findings.

Various hypotheses exist in the literature regarding the mechanism underlying the formation of traumatic syringomyelias.[15-19] One of the most notable theories that maintains its validity is that the cerebrospinal fluid undergoes a vortex effect inside the central canal after trauma, and therefore, plays a role in the development of syringomyelias.[20]

Because vertical forces can affect the entire length of the cord, the vortex effect on the cerebrospinal fluid inside the central canal may lead to the formation of syringomyelias. Syrinx cavities do not form in the acute period during trauma; however, the resistance in the walls of the central canal may decrease over time with a reduction in elasticity, allowing the formation of a

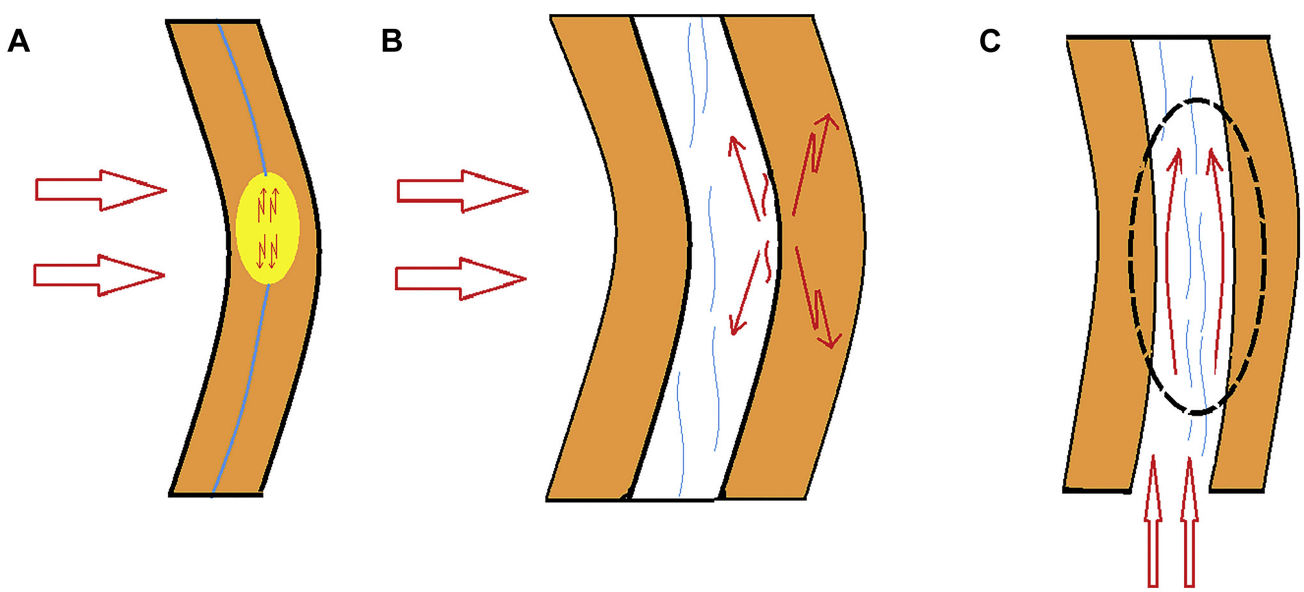

Figure 3. The effect that axial trauma has on limited segments in the cervical region are depicted in (**A**). The stress injury that high-energy axial trauma could create in the posterior region of the cervical spinal cord due to the effect of flexion-extension is depicted in (**B**). High-energy vertical trauma resulting in the appearance of a syringomyelia due to the vortex effect inside the central canal at thoracal level is depicted in (**C**).

Figure 4. Axial views of spinal cord injuries on the late period. A type of cavitary lesion (**A**), syringomyelia (**B**), and stretch injury (**C**) in the spinal cord.

syrinx cavity (Figure 3C). On the other hand, axial forces create a flexion-extension injury in the cervical part of the spine, and a significant vortex effect is not anticipated as the central canal is relatively narrow. A cord injury involving stretching of the cord forward and backward is considered more likely (Figure 3A, B). Therefore, axial traumas are not expected to create syringomyelia cavities directly according to the vortex theory. Accordingly, it was found in the present study that exposure to vertical forces frequently resulted in syrinx cavities in the thoracic region and patients subjected to axial forces presented with stretch injuries and cavitations in the cervical region.

In defining the etiopathogenesis of traumatic syringomyelia without findings of external compression of the cord, patients with spinal concussion can be considered to bolster the vortex theory. The type and direction of the high energy trauma inflicted on the spine may predict syringomyelia development. Therefore, investigating whether the cases who received a diagnosis of syringomyelia at initial admission were previously diagnosed with spinal concussion would serve as a guide in uncovering the etiology.

Findings and data obtained from neurological examinations allow inferences about which tracts of the cord may be involved. However, the cord injuries reported in the present study did not belong to the acute period and were diagnosed in the late period using radiologic tools. Thus, it must be considered that the predominant tracts manifesting findings are not yet affected, that inflammatory progressions may begin in certain regions of the cord, which do not present significant neurological deficits, and that in the long-term, these inflammatory changes can affect tracts, which may in turn present significant neurological findings. The inflammatory processes in the cord can be further investigated with data from comprehensive spinal concussion series or with animal experiments where spinal concussion models are created. We believe that cord injuries, which cannot be detected radiologically at the present time, will be demonstrated with radiologic tools and revealed in experiments in the following years with the advances in MRI technology and experimental studies.

CONCLUSIONS

Cases of spinal concussion constitute a group of patients who are rarely diagnosed. Because no findings can be obtained radiologically, differential diagnosis from real SCIWORA must be made in the early period. These cases may present with cavitary lesions in the cord and syringomyelias, which are diagnosed at a rate of >15% in the late period.

It is also possible that these patients will be mistaken for cases where the clinical findings and neurological deficits are masked because the cord injury is in tracts other than those that demonstrate significant clinical findings such as the spinothalamic and corticospinal tracts or tracts of the posterior column. Cord injury may not be detected with MRI in the early period, and a symptomatic period may appear in the long term due to inflammatory progression at the site of injury, resulting in the formation of cavitations or syringomyelia.

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