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Traumatic Syringomyelias: A Critique on the Basis of the Vortex Effect Theory

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ABSTRACT

Introduction: The current study aimed to investigate the clinical and radiological follow-up of patients with spine trauma after a post-traumatic syringomyelia diagnosis and to explore ongoing theories in the literature and the vortex effect in pathogenesis.

Methods: The records of 44 patients with a history of high-energy spinal trauma who were diagnosed with post-traumatic syringomyelia were retrospectively examined. The cases were divided into two groups: those affected by axial forces and those affected by vertical forces. The spinal MRI scan results were recorded. The association of trauma type with syringomyelia localization and size was indicated by pathogenesis.

Results: The mean age of the patients was 39.8 (26 males and 18 females). Ten (58.8%) cases indicated cervical syringomyelia, four cases (23.5%) indicated cervicothoracic syringomyelia, and three cases (17.6%) indicated thoracic syringomyelia due to axial trauma. As a result of vertical forces, six cases (22.2%) indicated cervical syringomyelia, four cases (14.8%) cervicothoracic syringomyelia, and 17 cases (62.9%) indicated thoracic syringomyelia. Segmental asymmetries were commonly observed in their neurological findings.

Conclusion: Syringomyelia was observed mostly in the cervical and cervicothoracic junction as a result of the impact of axial forces on the vertebral column. However, syringomyelia was observed mostly in the thoracic segments as a result of vertical forces. When considered along with the mechanisms of syringomyelia formation, it is possible that the manifestation of syringomyelia is due to a vortex effect inside the central canal.

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Introduction

Syringomyelia, which is defined as an abnormal expansion of the central canal inside the spinal cord, is a clinical problem that manifests due to deficits caused by this expansion. The cavitations, which were first described in 1550 by Estiene during cadaver dissections, were later defined as syrinxes by Charles Oliver d'Angers in 1827. Post-traumatic syrinx was first reported by Bastian (1).

A definite and clear description of how syringomyelia develops has still not being defined although theories exist to explain the pathogenesis (1). Syringomyelia frequently appears in comorbidity with Arnold Chiari malformations and tethered cord syndrome, also post-traumatic syringomyelia has been reported, suggesting that the proposed theories may fall short of explaining the pathogenesis of syringomyelia alone and that different mechanisms may be involved (1-5).

Traumatic syringomyelia appears a while after spine trauma and receive a late diagnosis.

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It may be detected incidentally and inspection of the spine trauma in these cases helps reveal the etiology. Clinical findings range from sensory deficits to advanced motor function loss of great variety.

In this study, results from the clinical and radiologic follow-up of 44 cases with spinal trauma and a diagnosis of syringomyelia were evaluated. Localizations of syringomyelia were determined, and their segmental measurements were performed. Pathogenesis of formation was described based on the obtained data, and it was shown that syringomyelia could appear after trauma due to a vortex effect inside the central canal.

Materials and Method

Records of 44 cases diagnosed with post-traumatic syringomyelia from 2013 to 2018 were studied retrospectively. Cases with high energy trauma in their medical histories were divided into two main groups and evaluated: those impacted by axial forces and those impacted by vertical forces. None of the cases received a diagnosis of spinal injury in their early examinations. Spinal MRI scans of all the cases were evaluated; syrinx localizations and segmental lengths, diagnosis time, and the symptomatic post-traumatic period began were recorded. Case distribution is demonstrated in Table 1.

Regions where the detected syrinxes were evaluated are distributed into three groups: cervical, cervicothoracic, and thoracic regions. Segmental measurements of the syrinx cavities were performed within each group, and the outcomes were compared across groups. Using the MRI follow-up reports of the cases, the greatest segmental lengths of the syringomyelia cavities that were detected were recorded.

Table 1: Demographic distribution of the cases (n=44)

Sex	
Male	26 (59,1%)
Female	18 (40,9%)
Initial Diagnosis Time	
<1 year	16 (36,4%)
1-3 years	24 (54,5%)
>3 years	4 (9,1%)
Follow-up Time	
<1 year	3 (6,8%)
1-3 years	22 (50,0%)
>3 years	19 (43,2%)
Primary Symptom	
Paresthesia	29 (65,9%)
Motor deficit	4 (9,1%)
Radicular Pain	27 (61,3%)
Incidentally	3 (6,8%)

Segment measurements were compared across cases affected by axial forces and cases affected by vertical forces.

Cases excluded from the study were those that presented findings of external pressure on the spinal cord and thus received a spinal fracture diagnosis and cases that previously underwent spine surgery.

Statistical Analyses

All data was organized in an Excel database file. The chi-square test and Fisher's exact test (two-tailed; nonparametric) were applied to evaluate group differences. A probability value <0.05 was set as statistically significant. All statistical calculations were performed using the software SPSS, version 20.0 (Statistical Package for the Social Sciences, Chicago, IL, USA).

Ethics committee approval was obtained from Ahi Evran University Clinical Research Ethics Committee (No:20-18-06/60).

Results

The cases comprised 44 cases (26 males and 18 females). The mean age was 39.8±13.7 years (range: 17-67). Investigations of etiology revealed that of the 27 (61.3%) fall cases, 23 were agricultural workers who fell from heights, and four were cases of fall from a tall building. Seventeen (38.7%) cases resulted from car accidents. The most common complaints were neck pain, sensory deficits in the extremities, loss of strength. The most common findings in the neurological examinations were dysesthesia and hypoesthesia. The mean time from the history of spine trauma was 41.6±16.9 months (14-88 months), and the time between the start of symptoms and the radiological diagnosis was 17.9±11.3 months (7-52 months).

None of the cases described any permanent neurological deficits that started right after the trauma and lasted until syringomyelia diagnosis. Forty-two cases were evaluated right after experiencing trauma and did not received any diagnosis related to spinal cord injury. Eleven cases reported temporary neurological deficits that lasted up to two days after trauma and recovered completely. It was inferred that the cases did not receive a SCIWORA or real SCIWORA diagnosis because they did not have lasting neurological complaints and were not diagnosed radiologically, and that the cases with temporary deficits were thought to experience a spinal concussion.

All patients reported that the symptoms showed variability during the time before diagnosis, and that they experienced periods during which their

Table 2: Localizations of syrinx cavities and their segmental measurements based on the type of high energy spinal trauma

	Cervical	Cervico-thoracic	Thoracic	Average of all segments
Axial Trauma n=17	10 (58,8%)	4 (23,5%)	3 (17,6%)	17 (100%)
Segment Avg.	1,6±0,9	2,0±0,8	2,7±0,6	2,2±0,8
Vertical Trauma n=27	6 (22,2%)	4 (14,8%)	17 (62,9%)	27 (100%)
Segment Avg.	1,9±0,4	2,7±0,5	3,6±0,9	3,4±1,08

complaints showed complete or nearly complete recovery. In five cases, pregabalin or gabapentin treatment was started due to paresthetic complaints that started a few months after trauma. However, treatment was ceased as there was either minimal effect on the symptoms or no amelioration at all. Neurological examination findings also showed variability during the follow-up period and that sensory and motor findings could present progression and regression. In cases with sensory and motor deficits detected, the cavity localization in MRI examinations and neurological exam findings did not present obvious results. There were myotomal and dermatomal findings with absolute boundaries that did not match the affected segment of the cord, and segmental asymmetries were observed.

Syringomyelia was most frequently detected in the cervical (58.8%) and cervicothoracic (23.5%) junctions in car accident cases and were thought to be affected by axial forces. In the thoracic region (62.9%), in those patients who fall from heights, they were thought to be affected by vertical forces (Table 2).

The segmental mean of syrinx cavity length was determined as 3.4±1.08 levels in cases of fall from height and 2.2±0.8 levels in car accident cases. Comparing syrinx segment lengths across the two groups revealed significant differences (p=0.127). The comparison of syrinx sizes across cervical, cervicothoracic, and thoracic segments, which were affected by axial and vertical forces, revealed that the segmental lengths of the syrinxes were significantly different (p=0.165) (Table 2).

Discussion

While syringomyelia is frequently encountered in comorbidity with cases like Arnold Chiari malformation and tethered cord syndrome, cases of post-traumatic syringomyelia are less common (6). In the literature, its prevalence after trauma was reported as 0.3%-3.2%(7,8). Clinical findings usually appear a long time after the trauma, and radiological diagnosis is made in the later period. The time at which the symptomatic period appears after trauma was reported to vary from 2 months to 32 years (9,10). It has been known that syrinx cavities can appear in the later progression in cases where cord injury is detected despite an asymptomatic course.

The pathogenesis of syringomyelia has not yet been described with certainty. The mechanism underlying syringomyelia formation was attempted to be explained by the hydrodynamic effects on cerebrospinal fluid (2), pulsatile CSF waves theory (3,11), and obstruction and blockage of CSF dynamics theory (4,12). While these theories fail to directly explain the appearance of traumatic syringomyelia, the formation of arachnoid scars due to the cord being exposed to pressure and intramedullary effects on the cord may have a part in the pathogenesis of traumatic syrinxes (5,9,13,14).

Another theory proposes that CSF inside the central canal creates cavities due to collision and vortex after trauma, resulting in syringomyelia inside the canal (15). A different theory states that the hematomas and ischemic events developed

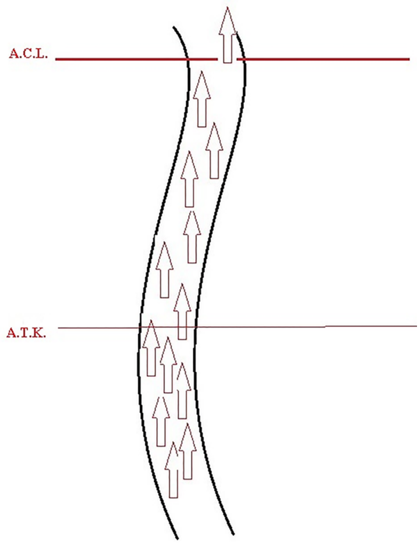

Figure 1: In cases of fall from height where the spine is exposed to vertical forces, the distal of the cord is affected more by the vortex effect. The vortex effect gradually decreases towards the apex of the thoracic kyphosis and particularly towards the apex of the cervical lordosis (A.C.L: apex of cervical lordosis, A.T.K: apex of thoracal kyphosis)

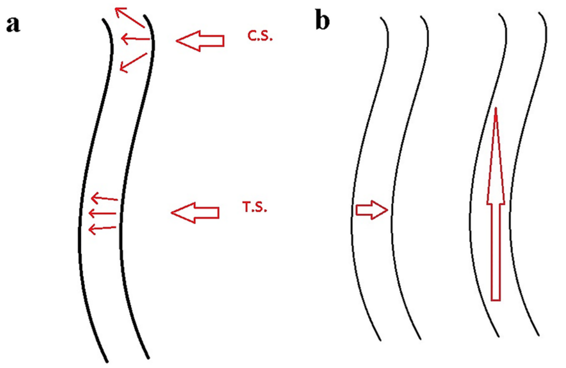

Figure 2: In cases where the spine is exposed to axial forces, since the cervical region is more mobile, the vortex effect inside the central canal is more pronounced in the cervical segments compared to the thoracic segments(a). Vortex effect is longer in thoracal segments than cervical segments (b) (C.S: cervical segments, T.S:thoracal segments)

inside the spinal canal cause cavitations to form in the long term. These cavities transform into syringomyelia over time (10,16). These theories are still valid in the etiology of traumatic syringomyelia.

In this study, 44 cases with spines exposed to high energy trauma and who were followed up with a diagnosis of traumatic syringomyelia were evaluated in two separate groups. In group 1, the spine was affected by axial forces, and in group 2, the spine was affected to vertical forces. The segmental lengths of the syrinx cavities were compared in both groups. In group 1, where the spine was exposed to axial forces, syrinx sizes in cervicothoracic and thoracic regions were significantly shorter than those of group 2, which was affected by vertical forces.

It is known that flexion-extension injuries are expected after the spine is exposed to axial forces. These injuries mainly affect the cervical region, which is more mobile. Axial forces cause the spinal cord in the cervical area to move forward and backward, resulting in a curve in the cord. The same effect may cause a limited vortex effect inside the central canal. However, this vortex effect is relatively weak as the axial length of the central canal is very short. On the other hand, when the spine is affected by vertical forces, a vortex effect that extends throughout the cord may occur inside the central canal (Figure 1). The spine is exposed to vertical forces that may impact all the length of the bone structures, however; inside the central canal, the vortex effect ends at the apex of the cervical lordosis where the curvature of the spine is more pronounced (Figure 2). The evaluation of all cases revealed that the syrinx cavity included the apex of the cervical lordosis in a total of three (6,8%) cases.

The syrinx cavities that appeared due to the

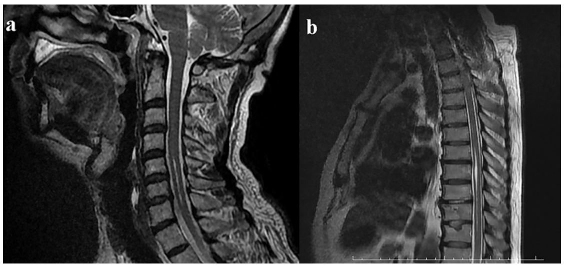

Figure 3: Syrinx cavity is limited at the apex of the cervical lordosis (a). Syrinx cavity is longer in thoracal segments after spinal trauma due to vertical forces. T10 vertebral body sclerosis and T11 superior end plate fractures due to history of spinal trauma were shown (b)

spine being affected by vertical forces had the longest length in the thoracic segments. Moreover, the effect of the vertical forces resulted in longer syrinx cavities in all segments. The exposure of the spine to vertical forces often impacted the thoracic region and the thoracic segments were those affected most frequently in cases that received a spinal concussion diagnosis following a fall from height (17). Thus, vertical forces create a greater vortex effect in the thoracic region where the spinal cord extends further (Figure 3). This causes a more prolonged vortex effect in the thoracic region and consequently, syringomyelia to develop in the longer segments. The impact of the vertical forces on the spine is interrupted in the apex of the cervical lordosis, where the curvature of the spine is greater and may not continue throughout the cord. For this reason, post-traumatic syrinxes detected in the thoracic or cervical regions are interrupted more frequently at the cervical lordosis region (Figure 1, 2b).

Syringomyelia cavities were most frequently detected in the cervical region because of the exposure of the spine to axial forces. The greater mobility of the cervical region than the thoracic region and its greater exposure to flexion-extension motion causes a more significant vortex effect to appear in this region and syringomyelia cavities to occur more frequently compared to the thoracic region (Figure 2a).

The MRI scans of the same cases at different times showed differences in syringomyelia cavity widths and segmental lengths. This suggests that the walls of the cavities created by the vortex effect inside the central canal showed different amounts of resistance at different times and that elasticity and resistance are reduced at the cavity walls due to the vortex effect. Therefore, decreased resistance at the central canal walls prevents syringomyelia cavities from appearing right after trauma, causing the syrinx cavity to form over time as tolerance decreases. The reduction and variability of resistance can explain the periods during which the width and the segmental length of the syrinx cavity manifests gradual reduction in follow-ups incorporating radiological evaluations.

Moreover, inspections of trauma histories in syringomyelia cases reveal that no spinal cord injuries were detected in the radiological evaluations done right after trauma, suggesting that these cases could be misdiagnosed as a spinal concussion or Real SCIWORA (18). The asymptomatic period that precedes the diagnosis of syringomyelia must be considered the tolerance period before forming a syrinx cavity.

In cases exposed to vertical forces, syringomyelia results from vortex effects encompassing greater segmental lengths than those caused by axial forces, corroborating the vortex theory that has been proposed to explain pathogenesis.

Conclusion

Traumatic syringomyelia may appear due to a vortex effect inside the central canal during trauma. The exposure of the spine to vertical forces results in the creation of syrinx cavities encompassing more segments. Syrinx cavities manifesting different widths and lengths at different times suggest that elasticity and resistance in the central canal walls are reduced due to the vortex effect. While vertical forces cause syrinxes to appear most frequently in the thoracic region and form more extended syrinx cavities, axial forces cause syrinxes to occur most frequently in the cervical region and form shorter syrinx cavities. The axial or vertical nature of the trauma may define the pathogenesis of the syrinx cavity through the vortex effect.

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