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Pathological changes of cervical spinal canal in cervical spondylotic myelopathy: A retrospective study on 39 cases

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A R T I C L E I N F O

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Dural sac area

A B S T R A C T

Objective: To evaluate and compare the cervical spinal canal (CSC) morphology among healthy people, cervical spondylosis myelopathy (CSM), and latent cervical spondylosis (LCS, people with cervical spine degeneration on medical imaging but without clinic symptoms). Patients and Methods: We reviewed MRI data describing cervical spinal morphology in healthy persons, LSC patients and CSM patients. All cases underwent cervical MRI. In transverse image, anteroposterior diameter (A–P diameter), area of cervical spinal canal (CSC) and area of cervical spinal cord were measured. In sagittal image, A–P diameter was measured. Dural sac area = the area of CSC in the transverse position – the area of cervical spinal cord in transverse position. Results: There're 8 cases in the healthy group, 18 cases in the group of LCS, and 13 cases in CSM group. Generally, the measured indicators at two ends of CSC (C2/3 and C7) are larger than those at C3–C6. A–P diameters on axial and sagittal position show a decrease trend from healthy group to LCS group and to CSM group. CSC area and dural sac area on axial position of CSM group are significantly lower than those in healthy group and LCS group. Almost all measured indicators of CSM group are significantly lower than healthy group and LCS group. Every two measured indicators in each group are significantly corelated. Conclusions: The results suggested that CSC size of CSM was smaller than that of LCS, and A–P diameter < 11 mm, CSC area $< 170\text{mm}^2$ and dural sac area $< 90\,\text{mm}^2$ were more advisable to indicate cervical spinal canal stenosis in Chinese people.

1. Introduction

Cervical spondylotic myelopathy (CSM) is the most common form of myelopathy in human. CSM is caused by spondylosis (arthritic changes) of the cervical spine, which results in spinal canal narrowing (spinal stenosis) and spinal cord compression ultimately [1]. Limb numbness, walk difficulty, dysuria, urinary retention, etc. are common symptoms of CSM, which bring lots of trouble to human's daily lives. Generally, cervical spine degeneration leads to cervical spinal canal stenosis. The clinic symptoms of CSM could appear when cervical spinal cord was compressed [2,3]. Thus, it's important for clinic practitioners to evaluate cervical spinal canal morphology. The cervical spinal canal (CSC) size plays an important role in spinal traumatic, degenerative, and inflammatory conditions, and thus it has to be evaluated [4].

There are a lot of studies on cervical spinal canal size and the relationship between cervical spinal canal size and spinal cord conditions [5,6]. A congenitally narrow cervical spinal canal has been established as an important risk factor for the development of CSM [7,8]. However, there are a group of people who show cervical spine degeneration on medical imaging but present no clinic symptoms. Those people may afterwards develop CSM and thus they could be considered as latent cervical spondylosis (LCS). Clinic practitioners should pay proper attention to LCS in order to prevent it from developing into CSM. However, it is still unknown if there is significant difference between CSC size of LCS and that of CSM. To the best of our knowledge, few reports thus far have described CSC morphology in patients with LCS. Therefore, it is important to study CSC morphology of LCS, and make a comparison between LCS and CSM.

Generally, CSC morphology was measured by X-ray, CT, CTM and MRI. X-ray was usually used to measure cervical canal in sagittal position [6,9,10], and it's easy and convenient to assess CSC but it lacks of preciseness [11]. MRI provides the most sufficient information and is routinely used for evaluation of spinal degenerative disease due to its ability to accurately delineate soft-tissue structures including intervertebral discs and spinal ligaments, and osseous structures [2]. MRI has high sensitivity in detecting spinal pathological changes due to its

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ability to detect subtle abnormalities in both soft-tissue and bone [12–14].

In this study, in order to evaluate and compare the CSC morphology among healthy people, LCS and CSM, we reviewed the MRI T2WI data concerning cervical spinal morphology. CSC morphology among healthy, LSC and CSM group was compared.

2. Patients and methods

2.1. Patients

This study was approved by the ethics committee of our hospital. The written informed consents of all patients were obtained. Thirty-nine volunteers who underwent cervical spinal MRI in Department of Orthopaedics and Traumatology, University of Hong Kong between February 2008 and December 2013, were included in this study.

The volunteers were classified into three groups, including healthy group, LSC group and CSM group, according to MRI results, clinical symptoms, JOA assessment and body examination. The criteria for the "healthy people" were JOA score = 17, no symptoms and no abnormal signals in the MR images. The criteria for LCS were JOA score > 11, slight (or no) clinical symptoms and no abnormal signals in the MR images. The criteria for CSM were JOA score < 11, obvious clinical symptoms and abnormal T2WI signals in the MR images. People who had any tumor history, cerebrovascular disease, or surgical history were excluded.

2.2. MRI scan protocol

All cases underwent cervical MRI using 3.0-Tesla MRI scanner (Philips Achieva, Netherlands). Patients were in the supine position with head in neutral position. The patients were required to make no swallowing actions, which could reduce motion artifacts. Electrocardiograph (ECG) triggered MRI was used to reduce cerebrospinal fluid artifacts. The imaging protocols included transverse and sagittal T2-weighted imaging using FSE sequence.

Scanning parameters for transverse imaging were as following: FOV = 80 × 80 mm, slice thickness = 7 mm, slice gap = 2.2 mm, fold-over direction = anterior/posterior (AP), NEX = 3, resolution = 0.63 × 0.68 × 7.0mm^3 (T1WI) and 0.63 × 0.67 × 7.0mm^3 (T2WI), recon resolution = 0.56 × 0.55 × 7.0mm^3 (T1WI) and 0.63 × 0.63 × 7.0 mm^3 (T2WI), TE/TR = 8/1000 ms (T1WI) and 120/4000 ms (T2WI).

Scanning parameters for sagittal imaging were as following: Field of view (FOV) = 250 × 250 mm, slice thickness = 3 mm, slice gap = 0.3 mm, fold-over direction = Feet/Head (FH), Number of excitation (NEX) = 2, resolution = 0.92 × 1.16 × 3.0mm^3 (T1WI) and 0.78 × 1.01 × 3.0mm^3 (T2WI), recon resolution = 0.49 × 0.49 × 3.0 mm^3, Time of echo (TE)/Time of Repetition (TR) = 7.2/530 ms (T1WI) and 120/3314 ms (T2WI). Images through the center of each vertebra and intervertebral disc (C1–C7) on 12 transverse planes and on 11 mid-sagittal planes were obtained.

2.3. MRI data reconstruction and measurement

The data obtained from the MR images were saved in computer for subsequent calculations, which were performed using an MRIcro and Image J (NIH Image, Bethesda, USA). The straight line distances and irregular areas were measured on Image J. C2-3, C3, C3-4, C4, C4-5, C5, C5-6, C6, C6-7 and C7 in T2WI were measured. In transverse image, anteroposterior diameter (A–P diameter), area of CSC and area of cervical spinal cord were measured (Fig. 1). In sagittal image, A–P diameter was measured. Dural sac area = area of CSC in the transverse position - area of cervical spinal cord in transverse position. Considering the morphology of C1 and C2 and few cervical spondylosis occurring in C1–2, measurement of C1, C2 and C1/2 wasn't performed.

2.4. Statistical analysis

SPSS 18.0 software was used for statistical analysis. The results are expressed as the mean ± SD. The comparisons between every two groups were analyzed by paired *t*-test. The relationship between every two indicators in each group was analyzed by Bivarate Correlation analysis. $P < 0.05$ was considered to indicate significant difference.

3. Results

Fifty people were assessed and 11 people didn't met the inclusion criteria. Finally, 39 cases met the inclusion criteria and were enrolled into the study. There were 8 cases (3 males and 5 females) with average age of 47.3 ± 8.8 years old in the healthy group, 18 cases (10 males and 8 females) with average age of 51.2 ± 7.3 years old in LCS group, and 13 cases (7 males and 6 females) with average age of 53.1 ± 10.8 years old in CSM group. There were no significant difference in age and sex ratio among the groups. In the healthy group, there was not any imaging signs of intervertebral disc bulging and protruding, ligament hypertrophy, acquired spinal canal stenosis, or clinical symptoms; sensory and motion function was normal according to JOA assessment; Hoffman's sign was negative. In LSC group, there were signs of intervertebral disc bulging and protruding on MRI image; sensory and motion function was normal according to JOA assessment; Hoffman's sign was negative; they had no clinical symptoms. In CSM group, there were imaging signs of intervertebral disc bulging and protruding, clinical symptoms, and abnormal sensory and motion function according to JOA assessment; Hoffman's sign was positive.

A–P diameters on transverse image were 11.11 mm–12.43 mm, 10.02 mm–12.18 mm and 6.68 mm–10.76 mm in the healthy group, LCS group and CSM group respectively. CSC areas on axial T2WI were 167.92 mm^2 −214.01 mm^2, 172.33 mm^2 −226.63 mm^2 and 112.57 mm^2 −174.10 mm^2 in the healthy group, in LCS group and in CSM group respectively. Dural sac areas on axial T2WI were 93.90 mm^2 −129.05 mm^2, 89.00 mm^2 −147.14 mm^2 and 40.79 mm^2 −102.64 mm^2 in the healthy group, in LCS group and in CSM group respectively. A–P diameters on sagittal T2WI were 12.40 mm–13.68 mm, 9.45–12.90 mm −12.18 mm and 6.35 mm–11.14 mm in the healthy group, in LCS group and in CSM group respectively.

A–P diameter, CSC area, dural sac area on transverse T2WI, and A–P diameter on sagittal T2WI are shown in Fig. 2. Generally, the measured indicators at two ends (C2/3 and C7) of CSC are larger than those at C3–C6. A–P diameters on axial and sagittal T2WI show a decrease trend from healthy group to LCS group and to CSM group (Fig. 1). CSC area and dural sac area on axial image of CSM group are significantly lower than those of healthy group and LCS group. There is no significant difference in CSC area and dural sac area between healthy group and LCS group (Table 1).

As for comparison among the three groups, almost all measured indicators of CSM group are significantly lower than those in healthy group and LCS group (Table 1). Compared with the healthy group, A–P diameters of C3-7 were lower in LCS group, but without significant difference in most vertebrae; CSC area and dural sac area of C7 were higher in LCS group ($p = 0.047$ for CSC area and $p = 0.033$ for dural sac area).

As for relationship between those CSC parameters, every two measured indicators in each group are significantly corelated ($p < 0.05$; Table 2).

4. Discussion

It is important for clinical practitioners to precisely understand the size of CSC for making diagnosis and evaluating prognosis. Few reports thus far have described CSC morphology in LCS condition. In this study, we mainly found that there was significant difference in A–P diameter, area of CSC and area of dural sac between healthy group and CSM

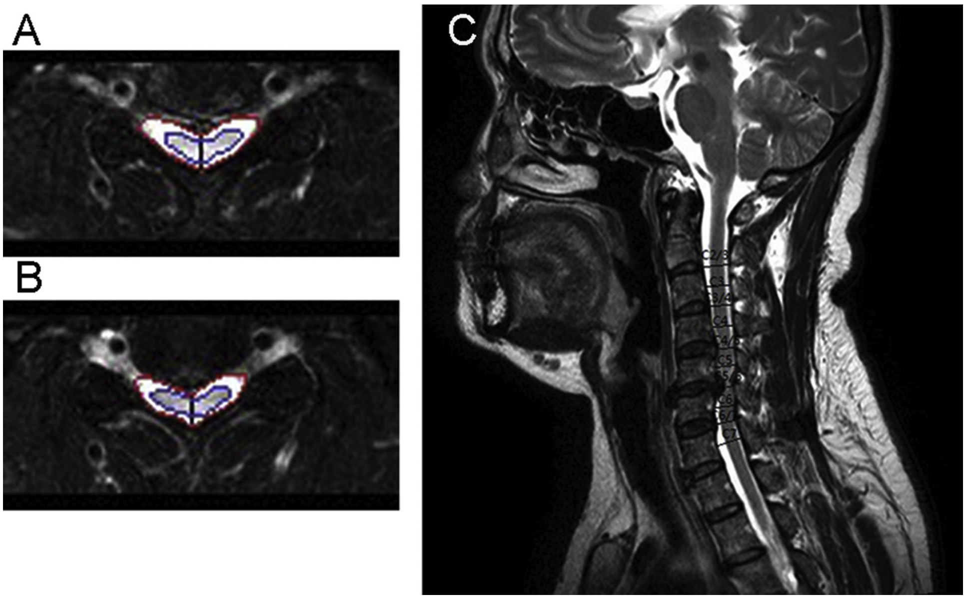

Fig. 1. Measurement of cervical spinal canal morphology on MRI image. A: Measurement at the center of cervical vertebral body on axial T2WI. Black line: anterior-posterior diameter of cervical spinal canal. Red line: the area of cervical spinal canal. Blue line: cervical spinal cord area. B: Measurement at the center of cervical intervertebral disc on axial T2WI. Black line: A–P diameter of cervical spinal canal. Red line: cervical spinal canal area. Blue line: cervical spinal cord area. C: Anterior-posterior diameter at all levels on mid-sagittal T2WI. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article).

group, and between LCS group and CSM group. Besides, every two measured indicators (A–P diameter, area of CSC and area of dural sac) in each group were significantly corelated.

For cervical canal measurement, the results varied among studies adopting different imaging tools and methods [6,15–17]. As far as we know, there is no report concerning A–P diameter in people with LCS. In the present study, A–P diameter in transverse position were 11.11 mm–12.43 mm in the healthy group, 10.02 mm −12.18 mm in the group of LCS and 6.68 mm –10.76 mm in CSM group; A–P diameter in sagittal position were 12.40 mm–13.68 mm in the healthy group, 9.45 mm–12.90 mm in the group of LCS and 6.35 mm–11.14 mm in CSM group. Therefore, A–P diameter < 11 mm was suggested as

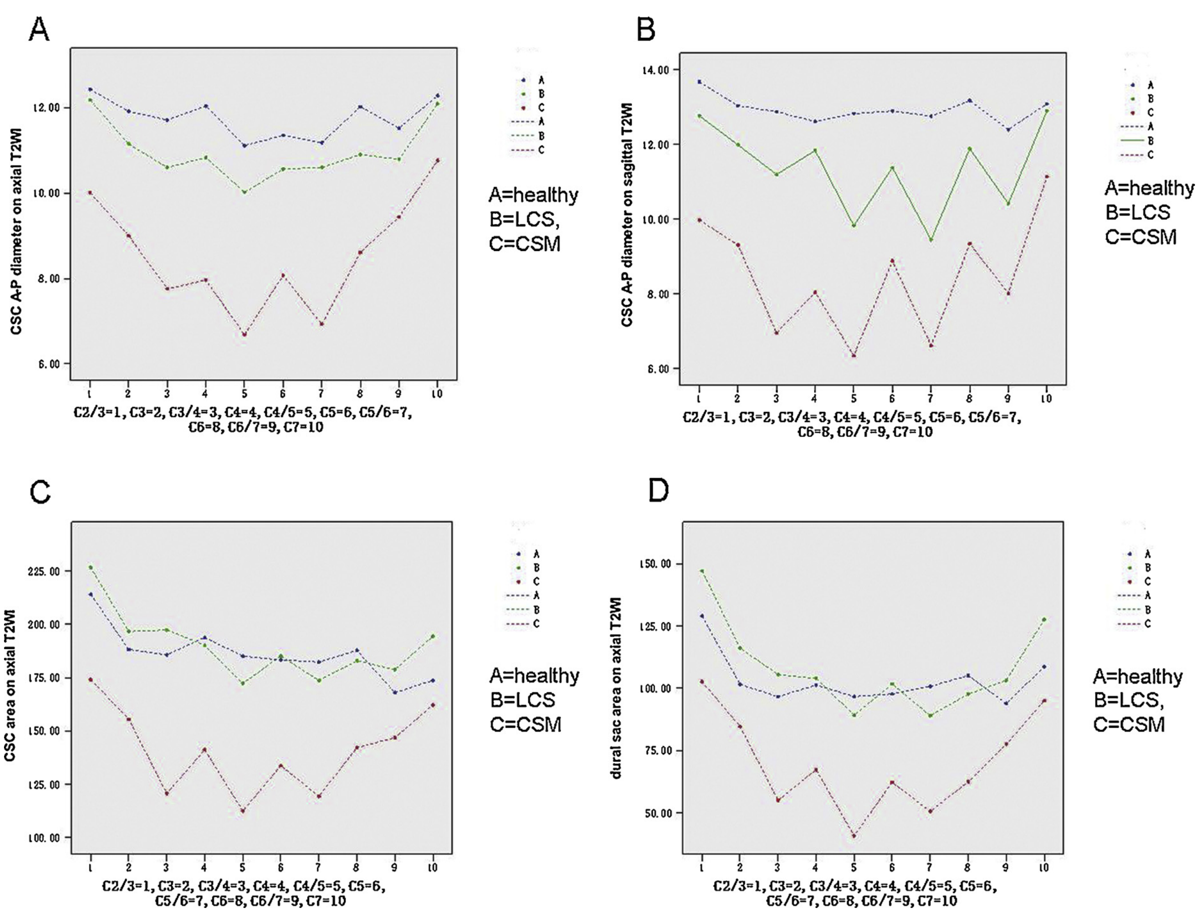

Fig. 2. Scatter plots showing the average values of the measurements. A: A–P diameter of CSC axial T2WI. B: Anterior-posterior diameter of CSC on sagittal T2WI. LCS: latent cervical spondylosis group. C: CSC area axial T2WI. D: Dural sac area on axial T2WI. CSM: cervical spondylotic myelopathy group. CSC: cervical spinal canal. A–P: anterior-posterior.

Table 1
Comparisons of all measurements between every two groups.

Parameters	Group	Measurement levels									
		C2/3	C3	C3/4	C4	C4/5	C5	C5/6	C6	C6/7	C7
CSC A-P diameter (axial)	A vs. B	0.703	0.149	0.049	0.021	0.06	0.091	0.417	0.052	0.288	0.724
	A vs. C	0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	0.006	0.012
	B vs. C	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	0.026	0.007
CSC A-P diameter (sagittal)	A vs. B	0.182	0.081	0.032	0.198	< 0.001	0.004	< 0.001	0.01	0.008	0.815
	A vs. C	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	0.002
	B vs. C	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
CSC area	A vs. B	0.383	0.392	0.478	0.717	0.253	0.882	0.494	0.638	0.417	0.047
	A vs. C	0.014	0 . 003	0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	0.14	0.285
	B vs. C	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	0.008	0.001
Dural sac area	A vs. B	0.156	0.084	0.4	0.719	0.369	0.669	0.235	0.45	0.439	0.033
	A vs. C	0.053	0.063	0.001	< 0.001	< 0.001	0.001	< 0.001	< 0.001	0.199	0.144
	B vs. C	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	0.016	< 0.001

A: Healthy group. B: Latent cervical spondylosis group. C: Cervical spondylotic myelopathy group. CSC: Cervical spinal canal. A–P: Anterior-posterior. Paired *t*-test was performed to compare between every two groups.

cervical spinal canal stenosis in our study, which was different from previous reports in which A–P diameter < 14 mm was considered as stenosis. [2,6] That might be partly attributed to the difference among Mongoloid race, Negroid race and Caucasus race. Probably for Chinese race, it is more advisable that A–P diameter < 11 mm indicates cervical spinal canal stenosis.

A–P diameter measured in mid-sagittal plane, is not able to reflect the real and whole condition of the cervical spinal canal, especially in the cases with intervertebral disc protrusion in the left posterior part or the right posterior part. Therefore, the area of CSC was studied in this research. Some reports said that prognosis might worsen with smaller area of CSC [17–19].Okada et al. [19] measured healthy human using MRI and the smallest area of CSC was 236.1 mm^2. Song et al. [20] measured 53 patients with cervical trauma and the area of CSC were 230.9-240.7 mm^2. Naganawa et al. [16] measured dural sac area in 45 cases with various cervical spinal diseases and the result was 144.9mm2 ± 40.9mm^2 when using CTM and was 130.0mm2 ± 39.0 mm^2 when using MRI. Machino et al. [21] reported that body position had influence on the measurement of cervical dural sac area; cervical dural sac area was smaller in the extension position than that in the flexion position. To avoid the influence of body position on measurement, neutral head position was adopted in our study. In the present study, the area of CSC was 167.92 mm^2 −214.01 mm^2 in the healthy group, 172.33 mm^2 −226.63 mm^2 in LCS group and 112.57 mm^2 −174.10 mm^2 in CSM group; the area of dural sac was 93.90 mm^2 −129.05 mm^2 in the healthy group, 89.00 mm^2 −147.14 mm^2 in LCS group and 40.79 mm^2 −102.64 mm^2 in CSM group. Therefore, for Chinese people, we thought that area of CSC < 170mm^2 and cervical dural sac area < 90 mm^2 might be more advisable to be considered as cervical spinal canal stenosis.

Compared with healthy group and LCS group, the measured indicators in CSM group were significantly lower. There was no statistical difference in the measured indicators except for anteroposterior diameter on sagittal T2WI between healthy and LCS group. This indicated that it seemed that those people without clinic symptoms didn't show significant difference in cervical spinal canal from those of healthy ones. It's noteworthy that there was statistical difference in A–P diameter of C3/4, C4/5, C5, C5/6, C6 and C6/7 on sagittal T2WI between healthy group and LCS group. We speculated that A–P diameter of CSC on sagittal T2WI could be used to distinguish LCS from healthy group, but which needs further study with a larger sample.

The measured indicators in C2/3 and C7 in the three groups were higher than those in other sections of cervical spinal canal. In C3–C6, the measured indicators of intervertebral discs were lower than those of their adjacent vertebrae, especially in CSM. This was in accordance to that intervertebral disc degeneration usually occurred in C3/4, C4/5, C5/6 and C6/7.

There are not many reports concerning the relationship between A–P diameter, area of CSC and area of dural sac. Song et al. [20] studied relationship between cervical canal anteroposterior diameter and cervical spinal canal area in patients with cervical spinal trauma, and they reported that r value was 0.07 − 0.58 which was lower than the value in our study. The present tudy showed that every two measured indicators in each group are significantly corelated.

The results might varied with different tools [16,22]. De Decker [22] reported that there was high consistency in spinal length and width, and vertebral length and width between CT and low field MRI. Naganawa [16] declared that the data concerning spinal canal obtained by CTM were significantly higher than those obtained by MRI; while the data concerning spinal cord obtained by CTM were significantly lower than those obtained by MRI. They thought that might be due to halo artifact of the contrast material.

Table 2
Relationship between every two measured indicators in each group.

Parameters	r value			
	Group A	Group B	Group C	General
CSC A-P diameter (axial) and CSC A-P diameter (sagittal)	0.69	0.684	0.74	0.830
CSC A-P diameter (axial) and CSC area	0.738	0.669	0.786	0.802
CSC A-P diameter (axial) and dural sac area	0.806	0.723	0.719	0.789
CSC A-P diameter (sagittal) and CSC area	0.723	0.532	0.676	0.720
CSC A-P diameter (sagittal) and dural sac area	0.724	0.520	0.613	0.680
CSC area and dural sac area	0.909	0.886	0.908	0.927

A: Healthy group. B: Latent cervical spondylosis group. C: Cervical spondylotic myelopathy group. CSC: Cervical spinal canal. A–P: Anterior-posterior. The relationship between every two indicators in each group was analyzed by Bivarate Correlation analysis.

In conclusion, our results suggested that CSC size of CSM was smaller than that of LCS, and A–P diameter < 11 mm, CSC area < 170mm^2 and dural sac area < 90 mm^2 were more advisable to indicate cervical spinal canal stenosis in Chinese people. We suggest that the patients with LCS should be followed up in regular basis. If necessary, proper therapy can be administered in order to prevent the disease from progress.

Conflict of interest

The authors declare that they have no conflict of interest.

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