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Original Article

Correlation between intramedullary signal change on T2-Weighted magnetic resonance images and prognosis in cervical spondylotic myelopathy

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Abstract: Objective: To characterize the correlations between intramedullary signal intensity (SI) changes on T2-Weighted magnetic resonance (MR) images in patients with cervical spondylotic myelopathy (CSM). Methods: Between October 2013 and December 2015, 106 patients with confirmed CSM who had been admitted to the Department of Orthopedics in our hospital and had received surgeries were enrolled in this study. One year after surgery, the eligible patients were assigned to the unchanged SI group (n = 20), the reduced SI group (n = 38) or the disappeared SI group (n = 48) according to the outcome of intramedullary high SI. The pre- and postoperative JOA scores, postoperative improvements in neurological functions and the area of high signal region were compared among the patients in the three groups. Pearson correlation analysis was used to analyze the correlation among intramedullary high signal area and intensity and JOA scores. Results: At 1 year after surgery, the JOA score was markedly higher than that of before surgery in each of the three groups (All P<0.05); the JOA scores were substantially different among the three groups (P<0.05), with the lowest JOA score in the unchanged SI group and the highest JOA score in the disappeared SI group. The area of high signal region was also significantly different among the three groups, with the largest area in the unchanged SI group and disappearance of high signal region in the disappeared SI group (P<0.05). In Pearson correlation analysis, there were correlations between the area of postoperative high signal region (r = 0.612, P = 0.002) and the postoperative intramedullary SI (r = 0.572, P = 0.001) and the JOA scores. Conclusion: After cervical decompression surgery, the patients with disappeared high SI had better prognosis. The maintenance of intramedullary high SI indicated poor prognosis, and there was a positive correlation between the intramedullary high SI and the JOA scores.

Keywords: Cervical spondylotic myelopathy, magnetic resonance imaging, T2-weighted high signal, prognosis

Introduction

Cervical spondylotic myelopathy (CSM) is a spectrum of spinal cord compression symptoms that arise when the spinal cord becomes compressed as a result of cervical disc herniation, degeneration of the intervertebral joint or osteophyte formation [1]. The Magnetic resonance imaging (MRI) of the cervical spine allows clear visualization of the anatomical structure of the spinal cord, the compression of the surrounding tissues and the changes in intramedullary signal intensity, which gives support to diagnosis and surgical care of the disease. The patients with intramedullary high signal intensity (SI) account for a larger proportion of those with cervical spondylotic myelopathy on T2-weighted image (T2WI) scans [2-4]. The clinical implication of the imaging signal changes has drawn increasing attention. The intramedullary signal changes on T2W images can be taken as the primary evidence for the diagnosis of spinal cord injuries. Intramedullary high SI reflects such pathological changes as edema, hemorrhage, inflammation, necrosis and softening of the spinal cord and gliosis [5]. However, the association between the changes in intramedullary high SI on T2W images and the clinical prognosis in patients are controversial [6, 7]. In this study, from October 2013 to December 2015, 106 patients with CSM who had been hospitalized and had undergone sur-

Figure 1. T2W images of each group. A: Preoperative intramedullary high signal intensity in the patients with unchanged signal intensity; B: No change in postoperative intramedullary high signal intensity in the patients with uncaged signal intensity; C: Preoperative intramedullary high signal intensity in the patients with reduced signal intensity; D: Significant reduced postoperative intramedullary high signal intensity in the patients with reduced signal intensity; E: Preoperative intramedullary high signal intensity in the patients with disappeared signal intensity; F: Disappearance of postoperative intramedullary high signal intensity in the patients with disappeared signal intensity.

geries were followed up, and the association between the changes in intramedullary high SI on T2W images and the clinical prognosis was examined in the patients.

Materials and methods

Patients

Between October 2013 and December 2015, a total of 106 patients with confirmed CSM admitted to the Department of Orthopedics in our hospital, who had received surgical treatment, were recruited in this study. Patients older than 18 years of age were eligible for enrollment in this study if they had confirmed CSM with the changes in intramedullary high SI as demonstrated by clinical symptoms and cervical CT or MRI examination; patients were consent to undergo cervical decompression surgery and had no relevant contraindications. Patients were excluded if they failed to complete the follow-up of at least one year, had had previous cervical spinal surgery, had intraspinal space-occupying lesion, cervical spondylosis of the nerve root or vertebral artery, or multi-organ dysfunction syndrome in the heart, liver, brain, lungs or kidneys. This study got approval from the Hospital Ethics Committee and all the patients and their families gave written informed consent.

MRI examination

All the eligible patients underwent MR imaging of the cervi-

Table 1. Comparison of baseline characteristics of patients among the three groups

Variable	Case	Male/Female (n)	Age (year)	Injury (d)	Approach to cervical decompression	
					Anterior	Posterior
USIG	20	13/7	40.6±12.5	6.4±1.7	11	9
RSIG	38	20/18	39.8±10.9	6.6±1.8	17	21
DSIG	48	25/23	40.2±11.3	6.2±1.6	23	25
F/X^2		1.055	0.034	0.594	0.554	
P		0.590	0.967	0.554	0.758	

Note: USIG denotes unchanged signal intensity group, RSIG reduced signal intensity group, DSIG the disappeared signal intensity group.

cal spine preoperatively and 1 year postoperatively with the use of a 1.5T magnetic resonance imaging scanner. The imagers were 1.5T MR systems. Placed in a supine position, the patient was given routine transverse and sagittal T1 and T2 weighted imaging with the application of surface coils. The parameters for sagittal T2-weighted images were set to be TR3000 ms, TE 100 ms, matrix size of 320*192, section thickness of 3 mm and section spacing of 0.3 mm. Two independent radiologists evaluated the MR images of the cervical spine for judging the changes in intramedullary high SI. The intramedullary high SI on T2W images was scored by the Yukawa method, with 0 point indicating normal signal, 1 indicating fuzzy signal, and 2 indicating intensive signal.

The Advantage Workstation AW 4.6 was employed for measurement of the area of high signal region on T2-weighted mid-sagittal MR images.

Surgical procedures

Anterior or posterior cervical decompression of the spine cord was performed based on the patients' conditions and relevant surgical indications. Methylprednisolone was administered before surgery, and the drainage catheter was removed at 2 days after surgery. Subsequently, dehydrating agents, antibiotic drugs and methylprednisolone were routinely administered at 3 days after surgery. The patients wore neck braces for fixing the necks for 2 months.

Cervical spinal cord function scores

The neurologic impairments of the cervical spine cord in the patients were examined with the use of the Japanese orthopedics Association (JOA) scoring system [8]. Scores range from 0 to 17 points, with 4 points for upper extremity function, 4 for lower extremity function, 6 for a tingling sensation, and 3 for urinary bladder function. The JOA scores of all patients were evaluated preoperatively and at 1 year postoperatively. Postoperative recovery ratio = [(Postoperative JOA score-Preoperative JOA score)/(17-Preoperative JOA score)]*100%. The SI value was measured by using the T2-weighted sagittal view of the spinal cord at the site of the greatest compression. If there were no great compression signal changes in the spinal cord, the SI was the value measured at the site of the greatest compression. Taken the SI at the site with normal signal on the same plane from the vertebral body C7 to the vertebral body C1 was taken as the control value. The value of intramedullary SI in the patient was expressed as the ratio between the two above values. The patients with the ratios of postoperative and preoperative intramedullary SI of less than 1/3 were assigned to the unchanged signal intensity group; those with the ratios of between 1/3 and 2/3 were assigned to the reduced signal intensity group, and those with the ratios of greater than 2/3 were assigned to the disappeared signal intensity group (**Figure 1**).

Statistical analysis

All statistical data were analyzed with the use of the SPSS software, version, 20.0. Measurement data were described as mean ± standard deviation; the paired t-tests were applied for intragroup comparisons of pre-and postoperative indexes; one-way analysis of variance followed by post-hoc Bonferroni tests were employed for comparisons among the three groups at the same time point. Enumeration data were expressed as percentages; the chi-square tests were used for comparisons across the three groups, whereas the chi-square partitioning tests were utilized for between-group comparisons ($P<0.05/3$ =

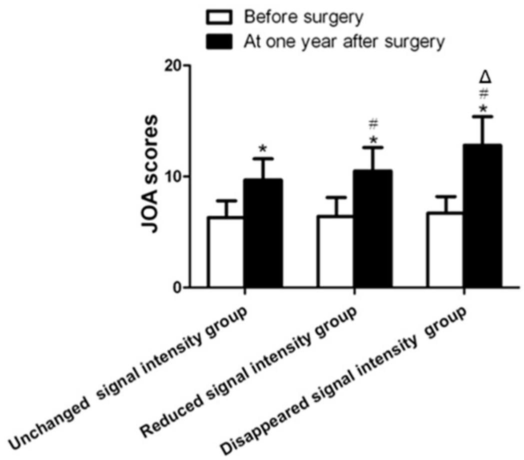

Figure 2. Comparison of the JOA scores among the three groups. *P<0.05 for the comparison of the JOA scores preoperatively and at one year postoperatively within each group; #P<0.05 for the postoperative comparison with the unchanged signal intensity group; ΔP<0.05 for the postoperative comparison with the reduced signal intensity group.

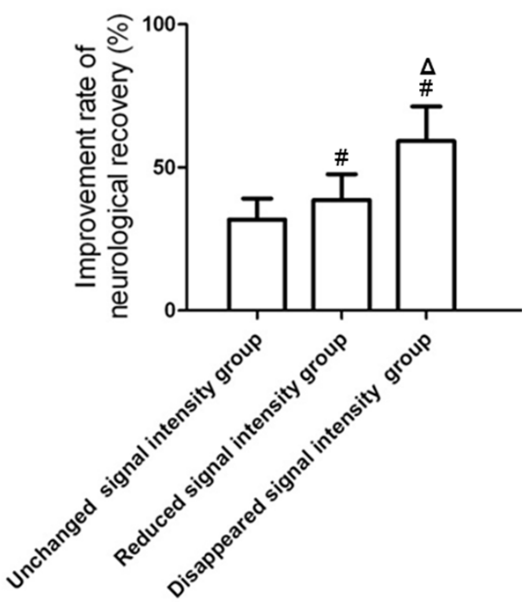

Figure 3. Recovery of neurological functions in the three groups at 1 year after surgery. #P<0.05 for the postoperative comparison with the unchanged signal intensity group; ΔP<0.05 for the postoperative comparison with the reduced signal intensity group.

0.017). The correlations among the intramedullary signal changes and the JOA score were characterized by Pearson correlation analysis. A *P* value of less than 0.05 was deemed statistically significant.

Results

Basic data of the patients

The patients were assigned to the unchanged signal intensity group, the reduced signal intensity group or the disappeared signal intensity group in terms of the cervical intramedullary high SI changes on T2W images at 1 year postoperatively. Slight differences were noted in gender, age, injury duration, surgical techniques between the two groups (P>0.05), hence their results were comparable (**Table 1**).

Pre- and postoperative JOA scores of the three groups

The mean preoperative JOA scores in the unchanged signal intensity group, the reduced signal intensity group and the disappeared signal intensity group were 6.3±1.5, 6.4±1.7 and 6.7±1.5, respectively. The preoperative JOA scores were insignificantly different across the three groups (F = 0.619, P = 0.541). The preoperative intramedullary SI values differed insignificantly across the three groups (5.8±1.1 vs 5.4±0.8 vs 5.6±1.0; P = 0.652).

One year after surgery, the JOA scores in the three groups were 9.7±1.9, 10.5±2.1 and 12.8±2.6, respectively. The pre- and postoperative JOA scores were significantly different in each of the three groups (All P<0.05). The reduced signal intensity group (P = 0.017) and the disappeared signal intensity group (P = 0.005) showed markedly higher postoperative JOA scores as compared with that of the unchanged signal intensity group, while the disappeared signal intensity group had strikingly higher postoperative JOA scores than the reduced signal intensity group (P = 0.008). The postoperative JOA scores were substantially different among the three groups (F = 17.119, P = 0.001; **Figure 2**).

One year after surgery, the rates of neurological recovery in the unchanged signal intensity group, the reduced signal intensity group and the disappeared signal intensity group were 31.8±7.3%, 38.6±9.0%, and 59.2±12.1%, respectively. The reduced signal intensity group and the disappeared signal intensity group had much higher rates of neurological recovery than the unchanged signal intensity group ((P = 0.034, P = 0.002, respectively) while the

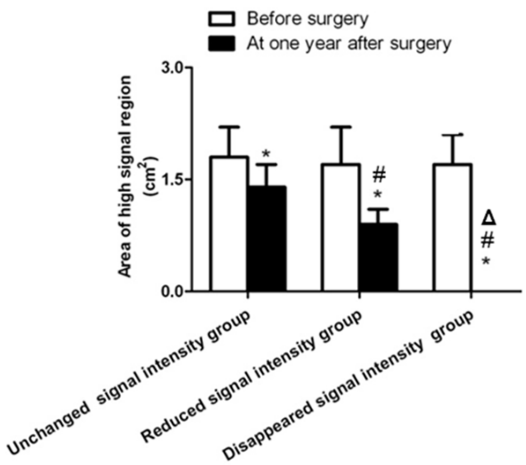

Figure 4. Comparison of the preoperative and postoperative area of high signal region among the three groups. *P<0.05 for the preoperative comparison in each group; #P<0.05 for the postoperative comparison with the unchanged signal intensity group; ΔP<0.05 for the postoperative comparison with the reduced signal intensity group.

disappeared signal intensity group had a much higher rate than the reduced signal intensity group (P = 0.003); the differences in the rates of neurological recovery were statistically significant among the three groups (F = 22.527, P = 0.001; **Figure 3**).

Pre-and postoperative area of high signal region

Insignificant differences were observed in the preoperative area of intramedullary high signal region among the unchanged signal intensity group (1.8±0.4 cm^2), the reduced signal intensity group (1.7±0.5 cm^2) and the disappeared signal intensity group (1.7±0.4 cm^2) (F = 0.422, P = 0.657). At 1 year after surgery, the area of intramedullary high signal region in the three groups were 1.4±0.3 cm^2 vs 0.9±0.2 cm^2 vs 0 cm^2; the preoperative and postoperative area of intramedullary high signal regions were greatly different within each group (P<0.05). The reduced signal intensity group and the disappeared signal intensity group demonstrated substantially smaller area of intramedullary high signal regions than the unchanged signal intensity group (P = 0.007, P = 0.001, respectively), and the disappeared signal intensity group reported substantially smaller area than the reduced signal intensity group (P = 0.002). The postoperative area of intramedullary high signal region was considerably different among the three groups (F = 395.550, P = 0.001; **Figure 4**).

Correlation between intramedullary high SI changes and JOA scores

Pearson correlation analysis demonstrated that the cervical intramedullary high SI and the area of high signal region were positively correlated with the JOA scores before surgery, respectively (r = 0.635, P = 0.003; r = 0.597, P = 0.002,); so were they after surgery (r = 0.572, P = 0.001; r = 0.612, P = 0.002, respectively), as shown in **Table 2**.

Discussion

CSM is a common disease leading to spinal cord dysfunction [9]. Cervical MRI not only quantifies the degree of spinal cord compression, but also clarifies the intramedullary signal changes. MRI is the most valuable tool for the diagnosis of CSM. It has greater advantages than CT and other examining tools [10]. Intramedullary signal changes have shown to reflect a variety of histologic changes, including edema, ischemia, gliosis, cavitation liquefaction and cystic degeneration [11-13]. A sea of prognostic factors affect CSM, including age, the course of disease, the severity of the disease, the rate of spinal cord compression at the site with the maximum compression, and intramedullary signal changes on T2W images [14, 15]. The correlation between intramedullary high SI and the clinical prognosis of CSM was first proposed by Takahashi et al. who held that intramedullary high SI represented poor prognosis, and was positively correlated with spinal cord compression and clinical conditions in patients [16]. Since then, multiple relevant studies have been carried out worldwide. However, the association between the intramedullary signal changes and the prognosis in CSM patients remains controversial. Mastronardi et al. and other researchers have reported that there is no significant correlation between intramedullary high SI on T2W images and the prognosis of patients with CSM, and intramedullary high SI on T2W images cannot be used as a predictor of prognosis in such patients [17]. Nevertheless, Shin et al. and other scholars have proven that intramedullary high SI on T2W images is a predictor of poor prognosis in patients with CSM [18].

Table 2. Coefficients of intramedullary high signal intensity and the area of intramedullary high signal region and JOA scores

Variable	Coefficient (r)	P
Preoperative		
Cervical intramedullary high signal intensity	0.635	0.003
Area of high signal region	0.597	0.002
Postoperative		
Cervical intramedullary high signal intensity	0.572	0.001
Area of high signal region	0.612	0.002

Therefore, it is of great significance to clarify the effect of intramedullary signal changes on T2W images on the prognosis of patients with CSM.

In our current study, the patients with CSM underwent cervical spinal cord decompression and were subsequently followed up for 1 year. The outcomes of intramedullary high SI on T2W images were analyzed among the patients in the three groups. At 1 year of follow-up, there were three types of intramedullary high SI changes, namely, no significant reductions in intramedullary high SI (the unchanged signal intensity group), a reduction in intramedullary high SI (the reduced signal intensity group) and disappearance of intramedullary high SI (the disappeared signal intensity group). The findings revealed that the postoperative JOA scores and the postoperative neurological functions improved markedly among the patients in the three groups, the improvement in postoperative neurological function showed an incremental trend with the decline in the SI. The patients with unchanged intramedullary high SI had the lowest rate of improvement in postoperative neurological function (merely 31.8%); those with reduced intramedullary high SI had a rate of 38.6%, and those with disappeared intramedullary high SI achieved the highest rate (59.2%). This suggests that the vicious cycle of "ischemia-edema ischemia" was under control after spinal cord decompression surgery, and the intramedullary pathological changes were partially or completely resolved, which were reversible [19]. Moreover, in this study, on one hand, among patients with mild spinal cord injuries, edema can be resolved quickly; the blood circulation is reestablished; no necrosis or cystic degeneration was present in the nerve cells and intramedullary high SI was disappeared completely on the T2W images. On the other hand, among patients with severe spinal cord injuries, there were necrosis of nerve cells and proliferation of glial cells, and no significant reductions in intramedullary high SI on the T2W images. Among the patients with severe injuries between the above two conditions, a decreasing trend of intramedullary high SI was shown on the T2W images, consistent with the finding reported by Chen et al. [20].

In addition, in our current study, we also compared the pre-and postoperative area of intramedullary high signal region among the patients in the three groups, and we found that in each of the three groups, the postoperative area of intramedullary high signal region was decreased markedly as compared with the preoperative area and showed a declining trend with the decrease in intramedullary SI, namely, the patients with unchanged intramedullary SI manifested the largest residual area of high signal region, followed by those with reduced intramedullary SI, and those with disappeared intramedullary SI had no residual area of high signal region. This suggests that the decrease in the area of the high signal region might reflect the improvement in the microenvironment of the injured spinal cord or the neurological recovery. Pearson correlation analysis demonstrated that the postoperative cervical intramedullary SI and the area of the high signal region were positively correlated with the JOA scores, suggesting that the postoperative cervical intramedullary SI and the area changes can be used as predictors of surgical outcomes, which is similar to the findings reported by Arvin et al. [21].

In conclusion, we had patients with CSM complicated with intramedullary high signal changes on T2W images undergone cervical cord decompression surgery. At 1 year of follow-up, we found there were diverse changes in intramedullary high SI. Better prognosis was observed in the patients with disappeared high SI, whereas poorer prognosis was in those with unchanged high SI. However, there are some limitations in this study, including a small sample size and short follow-up duration. Additional multicenter, randomized controlled trials with large sample size, and mid-and long-term follow-ups are needed for further validation.

Disclosure of conflict of interest

None.

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References

[1] Boogaarts HD and Bartels RH. Prevalence of cervical spondylotic myelopathy. Eur Spine J 2015; 24 Suppl 2: 139-141.

[2] Vedantam A and Rajshekhar V. Does the type of T2-weighted hyperintensity influence surgical outcome in patients with cervical spondylotic myelopathy? A review. Eur Spine J 2013; 22: 96-106.

[3] Machino M, Yukawa Y, Ito K, Nakashima H, Kanbara S, Morita D and Kato F. Can magnetic resonance imaging reflect the prognosis in patients of cervical spinal cord injury without radiographic abnormality? Spine (Phila Pa 1976) 2011; 36: E1568-1572.

[4] Yukawa Y, Kato F, Yoshihara H, Yanase M and Ito K. MR T2 image classification in cervical compression myelopathy: predictor of surgical outcomes. Spine (Phila Pa 1976) 2007; 32: 1675-1678; discussion 1679.

[5] Ma L, Zhang D, Chen W, Shen Y, Zhang Y, Ding W, Zhang W, Wang L and Yang D. Correlation between magnetic resonance T2 image signal intensity ratio and cell apoptosis in a rabbit spinal cord cervical myelopathy model. Chin Med J (Engl) 2014; 127: 305-313.

[6] Vedantam A, Jonathan A and Rajshekhar V. Association of magnetic resonance imaging signal changes and outcome prediction after surgery for cervical spondylotic myelopathy. J Neurosurg Spine 2011; 15: 660-666.

[7] Vedantam A and Rajshekhar V. Change in morphology of intramedullary T2-weighted increased signal intensity after anterior decompressive surgery for cervical spondylotic myelopathy. Spine 2014; 39: 1458-1462.

[8] Tong MJ, Hu YB, Wang XY, Zhu SP, Tian NF, Fang MQ, Xu HZ and Xiang GH. The spinal cord line can predict postoperative recovery for multilevel cervical spondylotic myelopathy. World Neurosurg 2017; 104: 361-366.

[9] Cuellar J and Passias P. Cervical spondylotic myelopathy a review of clinical diagnosis and treatment. Bull Hosp Jt Dis (2013) 2017; 75: 21-29.

[10] Xiong L, Zeng QY and Jinkins JR. CT and MRI characteristics of ossification of the ligamenta flava in the thoracic spine. Eur Radiol 2001; 11: 1798-1802.

[11] Chen CJ, Lyu RK, Lee ST, Wong YC and Wang LJ. Intramedullary high signal intensity on T2-weighted MR images in cervical spondylotic myelopathy: prediction of prognosis with type of intensity. Radiology 2001; 221: 789-794.

[12] Uchida K, Nakajima H, Takeura N, Yayama T, Guerrero AR, Yoshida A, Sakamoto T, Honjoh K and Baba H. Prognostic value of changes in spinal cord signal intensity on magnetic resonance imaging in patients with cervical compressive myelopathy. Spine J 2014; 14: 1601-1610.

[13] Sarkar S, Turel MK, Jacob KS and Chacko AG. The evolution of T2-weighted intramedullary signal changes following ventral decompressive surgery for cervical spondylotic myelopathy: clinical article. J Neurosurg Spine 2014; 21: 538-546.

[14] Zhang JT, Wang LF, Wang S, Li J and Shen Y. Risk factors for poor outcome of surgery for cervical spondylotic myelopathy. Spinal Cord 2016; 54: 1127-1131.

[15] Zhang JT, Meng FT, Wang S, Wang LF and Shen Y. Predictors of surgical outcome in cervical spondylotic myelopathy: focusing on the quantitative signal intensity. Eur Spine J 2015; 24: 2941-2945.

[16] Takahashi M, Yamashita Y, Sakamoto Y and Kojima R. Chronic cervical cord compression: clinical significance of increased signal intensity on MR images. Radiology 1989; 173: 219-224.

[17] Mastronardi L, Elsawaf A, Roperto R, Bozzao A, Caroli M, Ferrante M and Ferrante L. Prognostic relevance of the postoperative evolution of intramedullary spinal cord changes in signal intensity on magnetic resonance imaging after anterior decompression for cervical spondylotic myelopathy. J Neurosurg Spine 2007; 7: 615-622.

[18] Shin JJ, Jin BH, Kim KS, Cho YE and Cho WH. Intramedullary high signal intensity and neurological status as prognostic factors in cervical spondylotic myelopathy. Acta Neurochir (Wien) 2010; 152: 1687-1694.

[19] Tetreault LA, Dettori JR, Wilson JR, Singh A, Nouri A, Fehlings MG, Brodt ED and Jacobs WB. Systematic review of magnetic resonance imaging characteristics that affect treatment decision making and predict clinical outcome

in patients with cervical spondylotic myelopathy. Spine (Phila Pa 1976) 2013; 38: S89-110.

[20] Chen H, Pan J, Nisar M, Zeng HB, Dai LF, Lou C, Zhu SP, Dai B and Xiang GH. The value of preoperative magnetic resonance imaging in predicting postoperative recovery in patients with cervical spondylosis myelopathy: a meta-analysis. Clinics (Sao Paulo) 2016; 71: 179-184.

[21] Arvin B, Kalsi-Ryan S, Mercier D, Furlan JC, Massicotte EM and Fehlings MG. Preoperative magnetic resonance imaging is associated with baseline neurological status and can predict postoperative recovery in patients with cervical spondylotic myelopathy. Spine (Phila Pa 1976) 2013; 38: 1170-1176.