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Original Article

Changes of T2WI high signal of spinal magnetic resonance imaging correlated with the 1-year postoperative improvement rate in patients with cervical spondylotic myelopathy

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Abstract: Objective: The aim of this study is to investigate the relationship between T2WI high signal changes of cervical spinal magnetic resonance imaging (MRI) and 1-year postoperative improvement rate of patients in cervical spondylotic myelopathy (CSM). Methods: Sixty patients in CSM with spinal MRI T1WI equal signals and T2WI high signals were selected. After 1-year follow-up, patients were divided into high signal weakening group (group A, n=20), high signal invariant group (group B, n=22) and high signal enhancive group (group C, n=18) according to changes of spinal cord T2WI signal. Related indicators were compared, and Pearson correlation was applied. Results: The spinal cord compression rate of patients in each group was remarkably increased after surgery (all P<0.001). Compared with group A, the rate of transosseous compression and multi-segment high signal ratio were remarkably higher, the proportion of the single-segment high signal and postoperative modified Japanese Orthopedic Association score was remarkably reduced in group B and C (all P<0.001). There was a positive correlation between the change of cervical cord intramedullary signal intensity and the postoperative improvement rate (r=0.614, P=0.002). Conclusion: The change of cervical cord intramedullary signal intensity was positively correlated with the 1-year postoperative improvement rate and the reduced high signal intensity of T2WI after surgery indicates a significant postoperative improvement rate and the satisfying prognosis.

Keywords: Cervical spondylotic myelopathy, cervical spinal cord decompression surgery via posterior approach, magnetic resonance imaging, T2 weighted imaging high signal

Introduction

Under the impact of modern working style and working intensity, recent years have witnessed an increasing incidence of cervical spondylotic myelopathy (CSM), especially in the younger generation. It has become a serious threat to the patient's physical and mental health [1]. At the present, among the many imaging examination methods for CSM, cervical magnetic resonance imaging (MRI) emerges as the most important method. It can clearly reflect the anatomy structure of the spinal cord, spinal cord compression status and intramedullary changes [2, 3]. In recent years, more and more researches have attached attention to the signal changes of T1 weighted image (T1WI) and T2 weighted image (T2WI) in cervical MRI. It is shown that in patients with CSM, T2WI high signal intensity occupies a higher proportion [4, 5]. The changes in T1WI low signal followed with T2WI high signal suggests a poor prognosis [6, 7]. However, it remains controversial about the relationship between the changes in spinal cord T1WI equal signals with T2WI high signal and the postoperative prognosis. Hence, from January 2015 to December 2016, 60 patients with CSM hospitalized for cervical spinal cord decompression surgery via posterior approach were selected and followed up for one year. Accordingly, the research observed the changes of preoperative and postoperative T2WI high signal and explored its relationship with the rate of 1-year postoperative improvement, so as to investigate the guiding significance of intramedullary T2WI high signal to the clinical prognosis of patients in CSM.

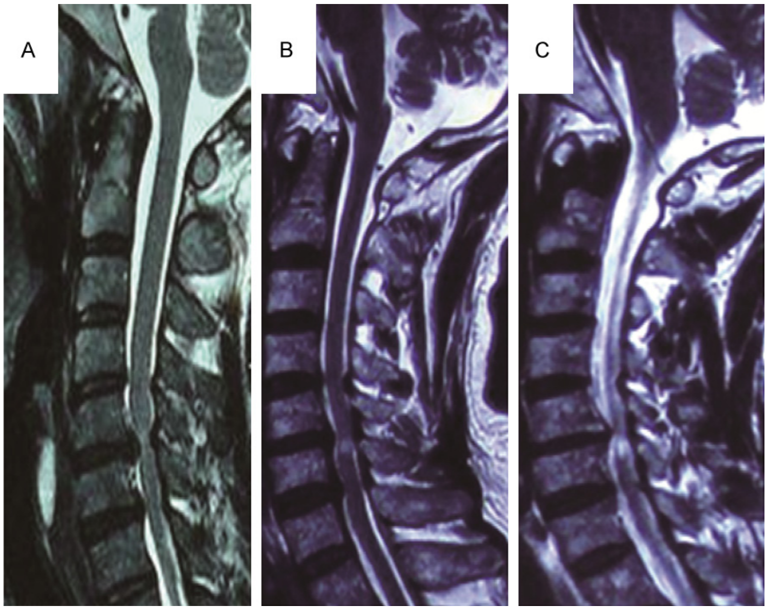

Figure 1. T2WI spinal cord signal intensity score. (A) 0 point, (B) 1 point, (C) 2 points. T2WI, T2 weighted image.

Material and methods

General information

This retrospective study was approved by the Ethics Committee of First People's Hospital of Shangqiu, and all the patients have signed the informed consent form. Sixty patients with CSM admitted to First People's Hospital of Shangqiu from January 2015 to December 2016 were enrolled as research targets. All procedures performed in studies involving human participants were in accordance with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Inclusion criteria: Patients (1) over 18 years old; (2) in line with CSM symptoms clinically and has been confirmed by cervical imaging examination; (3) with high signal changes in the spinal cord by preoperative T2WI MRI and equal signal changes by T1WI MRI; (4) who underwent spinal cord decompression surgery via posterior approach.

Exclusion criteria: Patients (1) with surgical contraindications; (2) unable to cope with postoperative follow up for at least 12 months; (3) with the history of cervical surgery, spinal cord tumors, nerve root type or vertebral artery type of cervical spondylosis, rheumatoid arthritis, infectious rheumatoid rheumatism and ankylosing spondylitis; (4) with heart, liver, brain, lung, kidney and other organ dysfunction; (5) recently taking glucocorticoid drugs.

According to the changes of spinal cord T2WI high signal between the last follow-up (1 year after surgery) and at preoperative time, patients were divided into the high signal weakening group, high signal invariant group and high signal enhancive group.

MRI examination

Selected patients were examined by 1.5T MRI 1 day before surgery and 12 months after surgery, respectively. To be specific, patients were taken supine position with routine T1WI and T2WI scanning on cross section and sagittal plane using surface coil. T1WI scan uses a spin echo sequence with sequence parameters TR 3,800 ms and TE 14.2 ms. T2WI uses a fast spin echo sequence with sequence parameters TR 3200 ms and TE 110 ms. The layer thickness was 3 mm, interval 0.3 mm and acquisition matrix 320×192. Two independent radiologists evaluated the cervical MRI images. The spinal cord sagittal and transverse diameters were measured using the Advantage Workstation AW 4.6 software on the MRI T2-weighted median sagittal image. The spinal signal intensity of T2WI was scored according to Yukawa's method: normal signal, 0 point; fuzzy signal, 1 point; bright signal, 2 points [8]. See **Figure 1**.

Cervical spinal cord decompression surgery via posterior approach

Posterior cervical median incision was made to separate and reveal the posterior bone structure. The small articular process was slotted at the 2 mm of the medial margin area by high-speed drill. The entire layer of vertebral plate was ground through from the opening side and the inner layer of cortical bone was remained from the opening axis side. The residual supraspinous and interspinous ligaments on the head and end were cut off. The entire vertebral plate was lifted along the opening axis after the interlaminar ligamentum flavum was stripped off. An appropriate length of titanium plate was bridging fixed. The surgical incision was rinsed with saline after C arm fluoroscopy position met demand. To finish with the whole surgery, drainage tube was indwelt, and wound was sutured layer by layer.

Postoperative treatment: Methylprednisolone Sodium Succinate for Injection (Pfizer, Inc., USA.) was given prior to spinal cord decompression, and the drainage tube was removed 2 days after the surgery. Dehydrating agents, antibiotics and methylprednisolone were routinely given 3 d after surgery. The cervical collar was requested to wear for 3 months.

Outcome measures

According to the changes of spinal cord T2WI high signal 1 year after surgery and preoperative signals, patients were divided into the high signal weakening group, high signal invariant group and high signal enhancive group.

The compression rate of spinal cord in the most severe lesion segment in each group 1 year after surgery was compared. The rate of spinal cord compression was defined as the ratio of the sagittal diameter and transverse diameter of the spinal cord in the most severe lesion [9]. The number of high signals in single-segment and multi-segment, as well as the types of spinal cord compression and the rate of transosseous compression in each group of patients were compared. And there were comparison of modified Japanese Orthopedic Association (mJOA) score and the clinical improvement rate. The cervical spinal cord function was evaluated by mJOA score method [10]. A total of 17 points includes upper limb motor function 4 points, lower extremity motor function 4 points, sensory perception 6 points, and bladder function 3 points. mJOA scores method was performed before surgery and 1 year after surgery for all patients. Postoperative improvement rate = ((postoperative mJOA score - preoperative mJOA score)/(17 - preoperative mJOA score)) *100%. In addition, we also analyzed the correlation between intramedullary signal changes and postoperative improvement rates, which was the main indicator. Besides, the other main indicator was postoperative improvement rate.

Statistical treatment

SPSS 20.0 software was used to perform statistical analysis of all data. The measurement data were expressed as mean ± standard deviation ($\overline{x}$ ± sd). Paired t test was used to compare the indexes before and after surgery within the group. One-way ANOVA together with Bonferroni test was used to compare among the three groups of patients at the same time point. Counting data was expressed as number/percentage. Chi-square test was used for comparison between groups. Pairwise comparison between groups was using partition of chi-square test. The relationship between intramedullary signal changes and postoperative improvement was analyzed by Pearson correlation method. Multiple linear regression analysis was applied to analyze the correlation, taking age, gender, preoperative JOA score, course of disease, lesion segment and quantity and changes of spinal cord T2WI signal intensity score as independent variables and postoperative improvement rate calculated by mJOA score as a dependent variable. $P<0.05$ indicated a statistically significant difference.

Results

Comparison of basic data

There were no significant differences in gender, age and duration of disease between groups (all $P>0.05$), thus they were comparable, as shown in **Table 1**.

Comparison of spinal cord compression rate

No matter before surgery or 1 year after surgery, the difference of spinal cord compression rate between three groups had no statistical significance ($F=2.647$, $P=0.084$; $F=0.684$, $P=0.523$). The spinal cord compression rate of the patients increased significantly after surgery compared to that before surgery (all $P<0.001$). See **Figure 2**.

Comparison of the types of spinal cord compression tissue

In high signal weakening group, there were 4 cases of transosseous tissue compression and 16 cases of fibrous soft tissue compression, making a transosseous compression rate of 20.00%. Ten cases of transosseous tissue

Table 1. Comparison of basic data ($\bar{x}$ ± sd, n (%))

Groups	High signal weakening group (n=20)	High signal invariant group (n=22)	High signal enhancive group (n=18)	F/χ^2	P
Male/female (n)	12/8	12/10	10/8	0.140	0.932
Age (year)	41.8±10.8	43.7±11.6	42.5±12.1	0.044	0.941
Duration of disease (month)	7.5±2.4	7.9±2.7	8.2±2.6	0.545	0.567
Diabetes	5 (25.0)	6 (27.3)	5 (27.8)	0.044	0.978
Hypertension	7 (35.0)	8 (36.4)	6 (33.3)	0.040	0.980
The number of involved segments				0.188	0.996
C3-4	7 (26.0)	11 (28.2)	8 (24.2)		
C4-5	11 (40.7)	15 (38.5)	13 (39.4)		
C5-6	9 (33.3)	13 (33.3)	12 (36.4)		

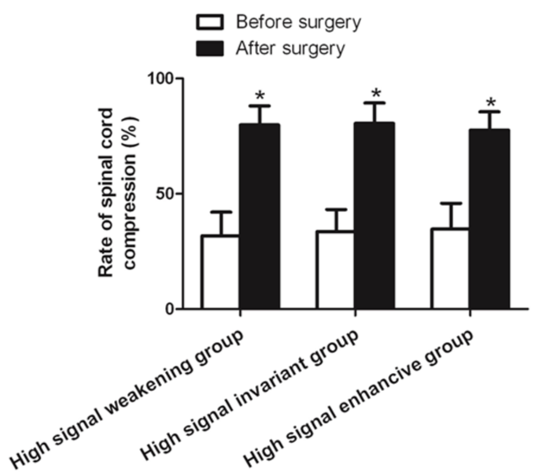

Figure 2. Comparison of spinal cord compression rates before and after surgery in each group. Compared with the same group before surgery, *P<0.001.

compression and 12 cases of fibrous soft tissue compression were found in high signal invariant group, resulting in a transosseous compression rate of 45.45%. In high signal enhancive group, the transosseous compression rate was 55.56% with 10 cases of transosseous tissue compression and 8 cases of fibrous soft tissue compression (**Table 2**). Compared with high signal invariant group or high signal enhancive group, high signal weakening group had significantly decreased transosseous compression rate (20.00% vs. 45.45%, 20.00% vs. 55.56%; both P<0.001). There was no significant difference in the rate of transosseous compression between high signal invariant group and high signal enhancive group (χ^2=0.404, P=0.525). See **Figure 3**.

Comparison of the single segments and multi segments proportion before surgery

Compared with high signal invariant group or high signal enhancive group, the proportions of single-segment high signal in high signal weakening group before surgery were significantly higher, while the proportions of multi-segment high signal were remarkably lower (all P<0.001). There were no significant differences in the high signal ratio of single segment and multiple segments between high signal invariant group and high signal enhancive group (P=0.897). See **Table 3**.

Comparison of mJOA scores and postoperative improvement rate

The preoperative mJOA score was 10.96±1.67 in high signal weakening group, 11.04±1.74 in high signal invariant group, and 10.79±1.58 in the signal enhancive group, without no significant difference (F=0.624, P=0.538). After one year of follow-up, the mJOA scores of three groups (15.20±1.29, 13.77±1.16 and 13.28±1.08, respectively) were all significantly increased compared to those before surgery (all P<0.001). One year after surgery, the mJOA score of high signal weakening group was significantly higher than that of high signal invariant group or high signal enhancive group (both P<0.001), but no significant difference was found between high signal invariant group and high signal enhancive group (P=0.357). See **Figure 4**.

Compared with high signal weakening group (70.2±6.22%), high signal invariant group

Table 2. Comparison of the type of spinal cord compression tissue (n, %)

Group	Transosseous tissue compression	Fibrous soft tissue compression	χ^2	P
High signal weakening group (n=20)	4 (20.00)	16 (80.00)	7.155	0.029
High signal invariant group (n=22)	10 (45.45)*	12 (54.55)*		
High signal enhancive group (n=18)	10 (55.56)*	8 (44.44)*		

Note: compared to the high signal weakening group, *P<0.05.

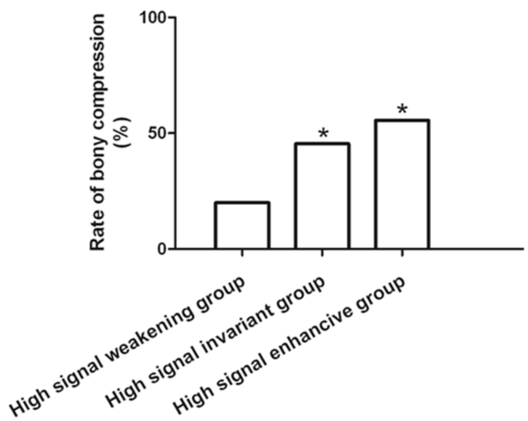

Figure 3. Comparison of the rates of transosseous compression the spinal cord in each group. Compared with high signal weakening group, *P<0.001.

(45.81±5.48%) and high signal enhancive group (40.1±5.39%) had a significant reduction in postoperative improvement rate with statistical difference (both P<0.001). It was not statistically significant for the difference in postoperative improvement rate between high signal invariant group and high signal enhancive group (P=0.268). See **Figure 5**.

Correlation between intramedullary signal changes and postoperative improvement

The results of the Pearson correlation analysis showed that there was a positive correlation between the changes of cervical intramedullary signal intensity before and after surgery and postoperative improvement rate of the patients (r=0.614, P=0.002).

Multivariate linear regression analysis

The independent variables were age, gender, preoperative mJOA score, course of disease, lesion segment and quantity, and changes of spinal cord T2WI signal intensity score. The dependent variable was the postoperative improvement rate of mJOA score. By stepwise regression method, the independent variables such as age (P=0.784), gender (P=0.804), course of disease (P=0.467), and lesion segments and quantity (P=0.512) were excluded, and preoperative mJOA scores and changes of spinal cord T2WI signal intensity scores were retained. Finally, the postoperative improvement rate of mJOA score =0.629 + 0.015* preoperative mJOA score + 0.012* changes of spinal cord T2WI signal intensity score (Inclusion criteria =0.10, exclusion criteria =0.15).

Discussion

CSM is a common spine degenerative disease in clinical orthopaedics, which is also the most serious type of cervical spondylosis [11]. Surgical treatment is the main method to relieve spinal cord compression, but the postoperative clinical results fail to live up to the expectation from time to time. It is reported that the clinical prognosis of patients with CSM can be affected by patients' age, course of disease, mJOA score, spinal cord compression rate, T2WI high signal and so on. However, the results of the different researches can hardly reach the agreement [12, 13].

MRI is currently recognized as the most valuable method for the examination of CSM. Some studies have reported that T2WI intramedullary high signal can reflect spinal cord edema, bleeding, inflammation, spinal cord necrosis and malacia, inflammatory response, and other pathological changes [14-16]. Spinal cord T2WI high signal can be divided into T1WI low signal/T2WI high signal, and T1WI equal signal/T2WI high signal. Alafifi et al. reported that T1WI low signal/T2WI high signal prompted a poor prognosis of the patients [17]. However, the relationship between cervical T1WI equal signal/T2WI high signal and prognosis has still been in doubt. For example, Shin et al. reported that the T2WI intramedullary high signal could be used as a monitoring indicator of poor progno-

Table 3. Comparison of the proportion between preoperative single segment and multi segment (n, %)

Group	Single segment high signal	Multi-segment high signal	χ^2	P
High signal weakening group (n=20)	15 (75.00)	5 (25.00)	6.557	0.038
High signal invariant group (n=22)	9 (40.91)*	13 (59.09)*		
High signal enhancive group (n=18)	7 (38.89)*	11 (61.11)*		

Note: compared to the high signal weakening group, *P<0.05.

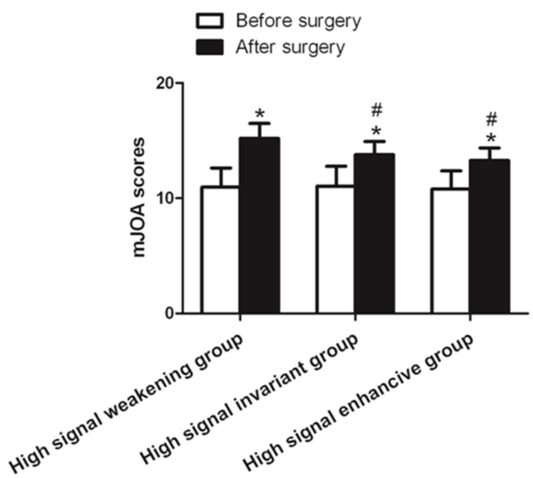

Figure 4. Comparison of mJOA scores between each group of patients. Compared with the same group before surgery, *P<0.001; compared with high signal weakening group, #P<0.001.

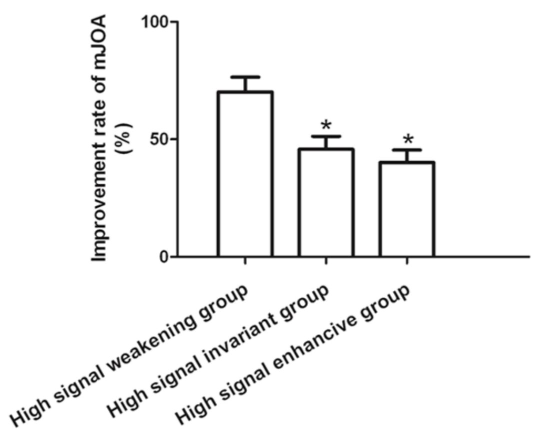

Figure 5. Comparison of mJOA improvement rates between each group of patients. mJOA, modified Japanese Orthopedic Association. Compared with high signal weakening group, *P<0.001.

sis in patients with CSM [18]. On the contrary, Mastronardi et al. reported no significant correlation that was found between T2WI intramedullary high signal and prognosis of patients with CSM, which meant that T2WI intramedullary high signal cannot be used as a prognostic indicator of such patients [19]. Therefore, it is of great significance to figure out the effect of the changes of T1WI equal signal/T2WI intramedullary high signal on the postoperative prognosis of patients in CSM.

In this research, patients with preoperative T1WI equal signal and T2WI high signal CSM received spinal cord decompression surgery by cervical posterior approach and were followed up for 1 year. The patients were divided into 3 groups according to T2WI high signal changes: high signal weakening group, high signal invariant group and high signal enhancive group. This research suggested that spinal cord high signal changes may be due to a serious pathological change such as ischemic necrosis, softening and cavities under the different compression over the spinal cord. On one hand, after spinal cord compression was relieved, spinal cord microcirculation was then improved and neural tissue began to repair, while ischemic edema inflammation and other reversible changes were recovered. Then the high signal intensity turned weakened in T2WI scanning. On the other hand, some irreversible pathological changes such as softening, necrosis and voids made T2WI high signal remain unchanged or enhanced. Some studies have shown that patients with T2WI high signal attenuation have better clinical efficacy [20, 21]. In this study, patients in T2WI high signal weakening group obtained the highest postoperative improvement rate and it was a positive correlation between the change of spinal intramedullary signal intensity and postoperative recovery improvement rate.

This correlation study showed that 1 year after surgery, postoperative mJOA score of high signal weakening group was significantly higher than that of high signal invariant group or high signal enhancive groups. To go further, the patients in high signal weakening group showed the single segment as the main high signal segment and fibrous soft tissue compression as the main type with a low transosseous compression rate. Therefore, it is easier for the T2WI high signal to reduce after decompression surgery with a better recovery of nerve tissue and function. The opposite situation was with the patients in the other two groups. Previous researches have suggested the number of lesions in T2WI high signal segment to be one of the indicators to evaluate the clinical prognosis. Patients with multi-segment T2WI high signal have even worse prognosis than those with single-segment high signal and decreased high signal intensity [22, 23]. Fibrous soft tissue is one type of the spinal cord compression tissues in CSM patients, which was mostly caused by the recent bad posture. As for this type of spinal cord compression, the spinal cord contusion changes were resulted by acute oppression and mostly reversible. If the spinal cord compression tissue is transosseous tissue, it may be caused by long-term cervical degenerative changes. The course of the disease is gradually aggravated. Spinal cord suffers softening and cavities and other irreversible pathological changes by chronic ischemic inflammation.

However, there are still some limitations in this research such as small sample size and short follow-up time, etc. It is needed to be further confirmed by multicenter, large sample, randomized controlled and long-term follow-up studies.

In summary, patients in CSM with preoperative T2WI intramedullary high signal were treated by spinal cord decompression surgery via cervical posterior approach. After surgery, different types of changes were found in intramedullary high signals during 1-year follow-up. Patients with high signal attenuation showed better clinical prognosis, while poor clinical prognosis showed in intramedullary high signal invariant or enhanced patients. It may be that there were mainly single-segment high signal and fibrous tissue type of spinal cord compression in patients with intramedullary high signal weakening after surgery.

Disclosure of conflict of interest

None.

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