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Original Article

Effect of intramedullary signal intensity on T2-weighted magnetic resonance images on prognosis in patients with thoracic spinal stenosis

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Abstract: Objective: To investigate the effect of intramedullary magnetic resonance (MR) changes on T2-weighted MR images (T2WI) on the postoperative prognosis in patients with thoracic spinal stenosis. Methods: Between January 2014 and December 2016, a total of 40 patients undergoing surgeries for thoracic spinal stenosis who had been diagnosed as having thoracic spinal stenosis in the Department of Orthopedics in our hospital were enrolled as subjects in this study. The enrolled patients were assigned to the high-intense signal group or the non-high-intense signal group in terms of the results of intramedullary signal intensity on T2WI of the thoracic canal. The preoperative JOA score, the rate of postoperative recovery and the severity of thoracic spinal stenosis were compared between the two groups. The patients in the high-intense signal group were stratified into some with increased signal intensity for single segment and the others with increased signal intensity for multiple segments according to the range of lesions, and the differences in the preoperative JOA score and the rate of postoperative recovery were compared between the two subgroups. Results: Compared to the non-high-intense signal group, the preoperative JOA score was markedly lower (4.5±1.5 vs 6.5±1.7; P<0.0001) but the proportion of patients with severe thoracic spinal stenosis was larger in the high-intense signal group (P<0.001). The rate of postoperative recovery was strikingly different between the two groups (38.5±14.6% vs. 48.9±17.8%; P<0.001). The preoperative JOA score and the rate of postoperative recovery were remarkably lower among the patients with increased signal intensity for multiple segments than those with increased signal intensity for single segment (Both P<0.001). Conclusion: The high signal intensity on T2WI of the patients with thoracic spinal stenosis demonstrates that more severe spinal cord injury indicates worse prognosis. The high signal intensity on T2WI can be used as one of the predictors for assessment of surgical prognosis of the patients with thoracic spinal stenosis.

Keywords: Thoracic spinal stenosis, magnetic resonance imaging, intramedullary high signal intensity

Introduction

Thoracic spinal stenosis is a set of clinical syndrome of spinal cord dysfunction caused by thoracic cord compression as a result of reduction in the thoracic transverse area which is impacted by various factors including developmental factors, ligament thickening and intervertebral disc degeneration [1, 2]. Once thoracic spinal stenosis is confirmed, surgery is the only applicable way to treat it [3, 4]. If it is not treated in time, irreversible damage would occur to the thoracic spinal cord. However, there are such neurological complications as paralysis in approximately 18-50% patients after a surgery for thoracic spinal stenosis [5]. The factors influencing surgical outcomes have been shown to be age, course of disease, the Japanese Orthopedic Association (JOA) scale score, operation technique, the degree, duration and rang of spinal cord compression [6]. Nevertheless, with only these preoperative data, it is difficult to evaluate and predict the prognosis of the surgery [7].

Magnetic resonance imaging (MRI) is one of the major radiological imaging examination tools for thoracic spinal stenosis. It has high sensitivity to the spinal cord lesion and clearly reflects the spinal cord compression and the intramedullary signal alternations [8, 9]. On T2-weighted MR images (T2WI) or T1-weighted MR images

Table 1. Comparison of general data of patients

Variable	High-intense signal	Non-high-intense signal	t/χ^2	P
Case (n)	20	20		
Male/Female (n)	14/6	15/5	0.125	0.723
Age (year)	50.2±3.1	51.4±3.6	1.130	0.266
Course of disease (mon)	11.2±1.8	10.7±1.5	0.954	0.346
Pathological segment (n)			0.682	0.839
Upper thoracic level	7	6		
Mid-thoracic level	3	5		
Lower thoracic level	10	9		
Clinical symptoms (n)			0.505	0.849
Chest and abdominal girdle sensation	7	9		
Intermittent claudication	8	7		
Fecal and urinary dysfunction	5	4		

Figure 1. T2WI of patients with thoracic spinal stenosis. A: Intramedullary non-high SI; B: Intramedullary high SI.

(T1WI), the area of the normal spinal cord shows moderate intensity signals. Some lesions of the spinal cord show high signal intensity (SI) on the T2WI images due to prolonged compression leading to ischemia, edema, degeneration, or necrosis. Multiple studies have demonstrated that the intramedullary high SI on T2WI in patients with cervical spondylosis is correlated with prognosis after surgery, but the relation between the prognosis after surgery for thoracic spinal stenosis and the high SI on T2WI is unclear [10, 11]. Therefore, in this study, 40 patients hospitalizing for thoracic spinal stenosis and undergoing the relevant surgery from January 2014 to December 2016 were followed up and the effect of preoperative high SI on T2WI on clinical prognosis were examined, aiding in support for assessing the surgical prognosis of thoracic spinal stenosis.

Materials and methods

Participants

From January 2014 to December 2016, a total of 40 patients undergoing the surgery for confirmed thoracic spinal stenosis in the Department of Orthopedics in our hospital were recruited as subjects. Patients older than 18 years old were eligible for enrollment if they were diagnosed as having thoracic spinal stenosis on thoracic CT or MRI, were consent to perform decompression in the spinal canal and intervertebral fusion with internal fixation, but no contraindications. Patients were excluded if they had complications of cervical spondylosis, intraspinal space-occupying lesion, lumbar spinal stenosis or osteoporosis, severe thoracic instability or deformity, or organ dysfunction in the heart, the brain, the lung, the kidney or other organs. This study obtained approval from the Hospital Ethics Committee and written informed consent was given by each patient or their families.

MRI examination

All the eligible patients underwent preoperative MRI examination on the thoracic vertebrae using 1.5T MRI (Siemens, German). The patients were placed in a supine position, and T1- and T2-weighted MR imaging of the transverse and sagittal planes was performed routinely of the thoracic spinal canal. The parameters regarding T2-weighted MR imaging of the transverse and sagittal planes were as follows: rapidly self-selected Huibo series, TR4000ms, TE 90ms, matrix 256 * 160, 4 mm of layer thickness, 0.5 mm of layer spacing, and 4 NEX. Two independent radiologists in spinal imaging evaluated the MRI of thoracic vertebrae, to determine if there was high SI in the spinal cord.

The thoracic narrowest level with the most severe stenosis was selected from sagittal

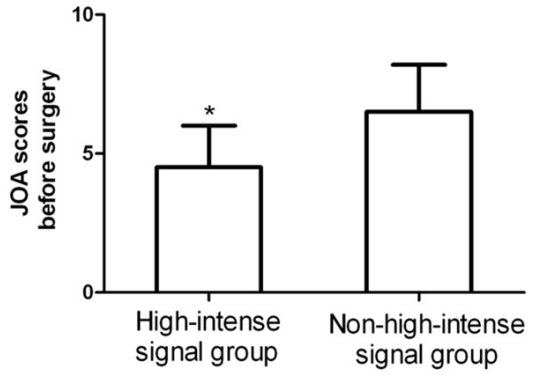

Figure 2. Comparison of preoperative JOA scores between the two groups. Compared with the non-high-intense signal group, *P<0.001.

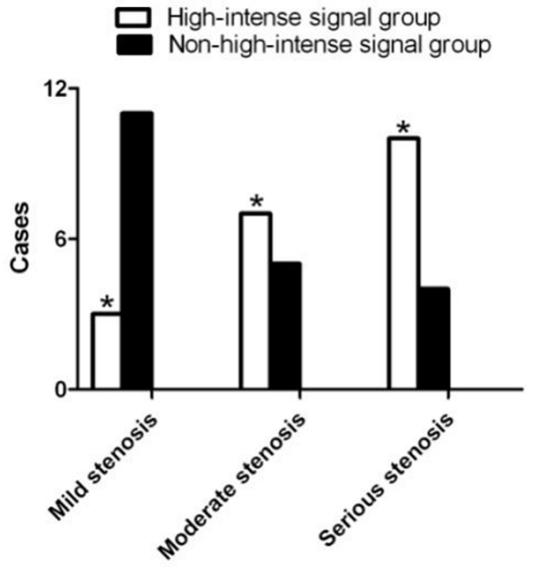

Figure 3. Comparison of the severity of preoperative thoracic spinal stenosis between the two groups. Compared with the non-high-intense signal group, *P<0.05.

images. The most serious compressed transverse area of the spinal cord and the transverse area of the spinal canal were examined using the Advantage Workstation AW 4.6 software, and the ratio of the two measured values is the residual rate of spinal canal area. The residual rate of the spinal canal area larger than 2/3 is considered mild stenosis; the rate is larger than 1/3 but less than 2/3 is considered moderate stenosis, and the rate less than 1/3 severe stenosis.

Thoracic spinal function score

The JOA scoring scale was utilized to assess the injury status in the thoracic spinal cord (on a scale of 11 points including 2 for physical sensory dysfunction, 4 for motor dysfunction in the lower extremity, 2 for sensory dysfunction in the lower extremity, 3 for sphincter dysfunction [12]. The JOA grading was performed in all the patients at 1 month preoperatively and postoperatively. The postoperative recovery rates were calculated according to the following equation: Postoperative recovery rate = [(Postoperative JOA score - Preoperative JOA score)/[(11- Preoperative JOA score)] * 100%.

Statistical analyses

All the data analyses were performed with the SPSS19.0 software. Measurement data were represented as mean ± standard deviation; a paired t-test was applied for intragroup comparison between preoperative and postoperative variables and the two independent-samples t-test was utilized for intergroup comparisons at the same time interval. Enumeration data were represented as percentage, and a chi-square test was used for intergroup comparisons. The *P* value less than 0.05 was deemed to be statistically significant.

Results

General data of patients

The eligible patients were assigned to the high signal intensity group (high-intense group, n= 20) and the normal signal intensity group (non-high-intense signal group, n=20) in terms of the SI of the thoracic spinal cord on T2WI. The patients in the two groups differed insignificantly in sex, age, course of disease, lesion segment and clinical symptoms (P>0.05), so they were comparable (**Table 1** and **Figure 1**).

Preoperative JOA score

The mean preoperative JOA score in the high-intense signal group (4.5±1.5) was substantially lower than that (6.5±1.7) in the non-high-intense signal group (P<0.001; **Figure 2**).

Preoperative thoracic spinal stenosis

In the high-intense signal group, mild thoracic spinal stenosis (the ratio of canal residual area is greater than 2/3) occurred in 3 patients (15%); moderate thoracic spinal stenosis (the ratio of canal residual area ranges from 1/3 to 2/3) occurred in 7 patients (35%) and severe thoracic spinal stenosis (the ratio of canal

Table 2. Comparison of the rate of postoperative recovery between the two groups

Variable	Case (n)	Postoperative JOA score	Postoperative recovery rate (%)
High-intense signal	20	7.0±1.6	38.5±14.6
Non-high-intense signal	20	8.7±1.9	48.9±17.8
t		3.061	2.604
P		0.004	0.013

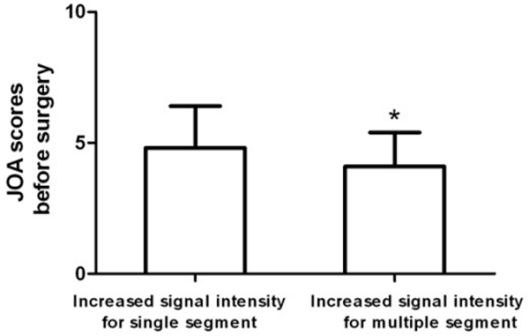

Figure 4. Comparison of preoperative JOA scores between the patients with increased signal intensity for single segment and those for multi segments. Compared with the patients with increased signal intensity for single segment, *P<0.001.

residual area is less than 1/3) in 10 patients (50%). In the non-high-intense signal group, 11 patients had mild thoracic canal stenosis (55%), 5 had moderate stenosis (25%) and 4 had severe stenosis (20%). The severity of thoracic spinal stenosis of patients was notably different between the two groups (P=0.024, **Figure 3**).

Rate of postoperative recovery

The mean postoperative JOA score was 7.0±1.6 in the high-intensive signal group and 8.7±1.9 in the non-high-intensive signal group, and there was a significant discrepancy in the JOA score between the two groups (P=0.004). Additionally, the rate of postoperative recovery was also markedly different, with (38.5±14.6)% in the high-intensive signal group and (48.9±17.8)% in the non-high-intensive signal group (P=0.013, **Table 2**).

Impact of increased signal intensity on clinical outcomes in the high-intense signal group

On the basis of the increased signal intensity on T2WI, the patients in the high-intense signal group were further stratified into some with increased signal intensity for single segment and others with increased signal intensity for multiple segments. Among them, increased signal intensity for single segment was present in 12 patients with preoperative JOA score of 4.8±1.6; increased signal intensity for multiple segments was present in 8 patients with preoperative JOA score of 4.1±1.4. There was a significant disparity in the preoperative JOA score between the two subgroups (t=9.014, P=0.018, **Figure 4**).

Apart from that, the postoperative JOA score was strikingly different, with 7.3±1.7 among the patients with increased signal intensity for single segment versus 6.6±1.5 among those with increased signal intensity for multiple segment (P=0.022). The rate of postoperative recovery was also strikingly different, with (44.3±15.7)% of the patients with increased signal intensity for single segment and (29.8±13.4)% of those with increased signal intensity for multiple segments (P=0.017, **Table 3**).

Discussion

Currently, MRI examination is a tool commonly used for the diagnosis of thoracic spinal stenosis. Compared to CT and other examination tools, MRI has more advantages [13]. On T2WI, intervertebral disc herniation and ossification of the ligament were present as low intense signals, the size, shape, range of the compressed components were seen clearly on the sagittal view and prognosis of the patients could be assessed according to the intramedullary signal changes [14]. According to a study, high signal intensity appeared on T2WI in approximately 41%-79% of thoracic spinal stenosis patients with ossification of the ligamentum flavum [15]. An analysis on the data from 16 patients with severe thoracic spinal stenosis revealed that up to 68.8% of the patients had changes in the intramedullary high signal intensity [16]. Although many patients with thoracic spinal stenosis had intramedullary high signal intensity on T2WI, scholars' knowledge of the high signal intensity on T2WI of the thoracic spinal cord is poor and the impact of high signal intensity on T2WI on the postoperative outcomes is controversial.

Recently, few studies have been implicated in the high signal intensity on T2WI of the thoracic spinal cord and surgical prognosis of patients

Table 3. Comparison of the postoperative recovery rates between the patients with increased signal intensity for single segment and those for multiple segments

Variable	Case	Postoperative JOA score	Postoperative recovery rate (%)
Single segment	12	7.3±1.7	44.3±15.7
Multiple segment	8	6.6±1.5	29.8±13.4
t/χ^2		8.887	8.143
P		0.022	0.017

with thoracic spinal cord, but the opinions are inconsistent. Previous studies have indicated that the intramedullary high signal intensity on T2WI is not correlated with the surgical effect, prognosis and the severity of spinal cord lesions; some patients with high signal intensity on T2WI have a favorable recovery after surgical treatment; the spinal cord lesion is a reversible change [17]. An assessment of the surgical outcomes of 24 patients with thoracic spinal stenosis revealed that intramedullary high signal intensity on T2WI could not be taken as a predictor of surgical outcomes [18]. Nevertheless, according to Eck et al. and He et al., among the patients with thoracic spinal stenosis, a poor postoperative recovery was observed in those with intramedullary high signal intensity on T2WI [7, 19]. In the current study, MRI was performed on 40 patients with thoracic spinal stenosis, and 50% of them had high signal intensity on T2WI.

Compared to the patients in the non-high-intense signal group, those in the high-intense signal group had a notably lower preoperative JOA score and a lower rate of postoperative recovery of the spinal cord, indicating that the high signal intensity on T2WI in the thoracic spinal cord had certain impact on the surgical prognosis of the patients with thoracic spinal stenosis. Moreover, the studies on the impact of intramedullary high signal intensity on the surgical outcomes have demonstrated that the preoperative JOA score and the postoperative recovery of the spinal cord are significantly higher among the patients who have increased signal intensity for single segment than those who have increased signal intensity for multiple segment, suggesting that the severity of spinal cord injury is correlated with the high signal intensity on T2WI, with greater extent of signal intensity on T2WI indicating more severe spinal cord injury. The current study suggests that the high signal intensity on T2WI of the thoracic spinal cord may be explained by long-term compression of the spinal cord, which gives rise to disturbance of intramedullary blood circulation, obstruction and congestion in the venous vessels and increased permeability in the vascular walls, leading to irreversible pathological changes, such as edema, degeneration and necrosis of the spinal cord. As the cord function is impaired seriously, the recovery of the spinal cord would be still worse even after timely surgical decompression. It is indicated that T2WI is used as a tool of imaging examination to examine the pathological changes in the spinal cord, and the intramedullary high signal intensity is partly correlated with the impairment of neurological function of the spinal cord.

There are a variety of methods for measuring thoracic spinal stenosis in MRI, including the ratio of the stenotic sagittal diameter of the spinal canal to the sagittal diameter of the vertebral body and the ratio of the sagittal diameter to the transverse diameter of the spinal cord. In the current study, we adopted the ratio of the most obvious compressed transverse area of the spinal cord to the transverse area of the spinal canal. In one study, a reduced rate of preoperative thoracic spinal stenosis had an obvious impact on postoperative recovery and tended to cause deterioration of preoperative function of the spinal cord, and the status and recovery of preoperative function of the spinal cord was closely related to the severity of stenosis of the thoracic canal [20]. The results of the current study demonstrated that compared to the non-high-intensive signal group, thoracic spinal stenosis was markedly deteriorated among the patients in the high-intensive signal group, indicating that the patients with high signal intensity on T2WI had more severe spinal stenosis, worse preoperative function and poorer postoperative recovery of the spinal cord. All this suggests poor prognosis of the patients.

In conclusion, high signal intensity on T2WI can be used as a predictor for assessment of postoperative prognosis of patients suffering from thoracic spinal stenosis. High signal intensity is correlated with the extent of spinal cord injury, with greater extent of high signal intensity indicating more severe spinal cord injury. Besides, high signal intensity also has an effect on the surgical prognosis of patients. However, there are some limits in the current study, such as the small sample size and short-term follow-up.

Additional multicenter randomized controlled studies with large sample size and mid-term and long-term follow-up studies are needed to make further validation.

Disclosure of conflict of interest

None.

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