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ORIGINAL STUDY

The effect of intramedullary signal intensity in MRI on the therapeutic efficacy of posterior cervical decompression laminectomy with internal fixation and fusion for multi-level cervical spondylotic myelopathy : a retrospective cohort study

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We aimed to investigate the effect of intramedullary signal intensity in MRI on the therapeutic efficacy of posterior cervical decompression laminectomy with fixation for multi-level cervical spondylotic myelopathy.

Fifty-six patients were retrospectively analyzed in two experimental groups: signal (-) group (n=41) and signal (+) group (n=15). JOA scores, Borden values, Cobb angles, disc space heights, and adjacent disc space heights of the cervical spine were measured to evaluate the neurological functional recovery rate.

The effective rate in the spinal cord signal (-)/(+) group was 95.1%/86.7% and the excellent (or good) rate was 85.4% (or 20.0%). A rank-sum test revealed a significant difference between the JOA score improvement rates of the signal (+) and signal (-) groups. Analyses of variance showed that the Borden values and Cobb angles, but not the disc space heights and inter-vertebral space heights, collected at these four time points were statistically different.

The signal (-) group improvement rate was higher than that of the signal (+) group despite the fact that posterior cervical decompression laminectomy with fixation effectively improved the overall neurological functions in all MCSM patients. Furthermore, the surgery provided good cervical stability throughout the whole observation period.

Keywords : cervical spondylotic myelopathy ; posterior decompression ; internal fixation ; signal change in MRI ; cervical stability

INTRODUCTION

Cervical spondylotic myelopathy (CSM) is a progressive cervical degenerative disease that can cause stenotic changes in the spinal canal as well as spinal cord compression. CSM was first reported by Brain etc. (Brain WR, 1952) in 1952 and has gradually become widely recognized and studied. CSM is one of the most common causes of spinal cord dysfunction. Ischemia of the cervical spinal cord is believed to be a significant contributor to the pathophysiology of CSM, which includes compression of larger vessels and impaired microcirculation (Baptiste DC, 2006). Surgical decompression with internal fixation and fusion is the most common procedure for the treatment of CSM patients with moderate to severe or progressive neurologic deficits (Toledano M,

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2013 ; Wang L, 2012). Magnetic resonance imaging (MRI) has been used both to investigate how the spinal cord is compressed anatomically and to assess the pathological changes within the spinal cord through changes in signal intensity in patients with cervical myelopathy (Matsuda Y.,1991; Ramanauskas WL., 1989). Cervical laminectomy with or without internal fixation has been widely used in the treatment of progressive myelopathy due to such stenotic conditions as CSM, OPLL, and developmental stenosis, especially for multi-level CSM (MCSM) (Lee SE, 2013).

While previous studies have examined both high signal intensity changes in T2-weighted imaging (T2WI) and contrast enhancement in T1-weighted imaging (T1WI), to our knowledge, very few studies have compared the prognostic significance and clinical development of these imaging parameters. This study retrospectively investigated the effect of intramedullary signal intensity on the therapeutic efficacy of posterior cervical decompression laminectomy with internal fixation for MCSM caused by intervertebral disc herniation or osteophyte formation at two or more levels.

METHODS

This retrospective cohort study conformed to the relevant ethics requirements. Specifically, this study received approval from the institutional review board of our hospital. We conducted this study with patients who were surgically treated for their conditions. The records of 76 patients who had undergone cervical laminectomy with internal fixation for MCSM at our department between December 2008 and November 2013 were reviewed.

Myelopathy was defined by disturbances in motor function that are associated with abnormal reflexes, muscle weakness, and sensory disturbances (Choi JH., 2014). Diagnosis of CSM was confirmed by radiological and MRI findings and included at least one “upper motor neuron” symptom (e.g., spasticity, hyperreflexia, or positivity for Babinski’s or Hoffmann’s sign) on neurologic examination (Carette S, 2005).

We carefully ruled out patients with acute traumatic cord injuries with cervical fractures or dislocations caused by high-energy trauma or with other confirmed neurological disorders (e.g., Parkinson’s disease, multiple sclerosis, demyelinating diseases, or polio). Patients were also excluded if they died, could not be located, or their data were missing before the follow-up evaluation. Furthermore, other exclusion criteria included previous or phase II histories of cervical spine surgery.

Of the initial 76 patients, 18 patients were lost at follow-up, leaving 58 patients (76.3%). Two of these patients had received phase II anterior cervical discectomy and fusion (ACDF), bringing the total number of included patients to 56. Among the 56 patients, 33 patients were diagnosed with two-level CSM, 17 patients with three-level CSM, and 6 patients with four-level or higher CSM. All 56 patients had cervical myelopathic symptoms and underwent posterior cervical decompression via cervical laminectomy with internal fixation and fusion for the treatment of myelopathy.

All patients had normal preoperative radiographs, results from three-dimensional computed tomography (3D CT), and results from high resolution MRI using a 1.5T GE MRI Medical System. The radiographic parameters included the intramedullary signal intensity on a T2-weighted MRI, Borden value (Borden AG, 1960), Cobb angle between the superior endplate of the upper vertebra and the inferior endplate of the lower vertebra (Yang X, 2013 ; Imagama S, 2010), the disc space height, and the adjacent disc space height (Figure 1). The parameters were measured at preoperative, immediate postoperative, 3-month postoperative, and final postoperative intervals to assess the therapeutic efficacy of the operation. The radiographic parameters were observed and assessed by two independent, blinded orthopedic surgeons. The final score for each patient was determined by averaging the values from the two observers. According to their intramedullary signal levels, the 56 patients were divided into a normal intramedullary signal (signal (-)) group (n=41) and an intramedullary T2-weighted high-intensity signal (signal (+)) group (n=15). The radiological studies

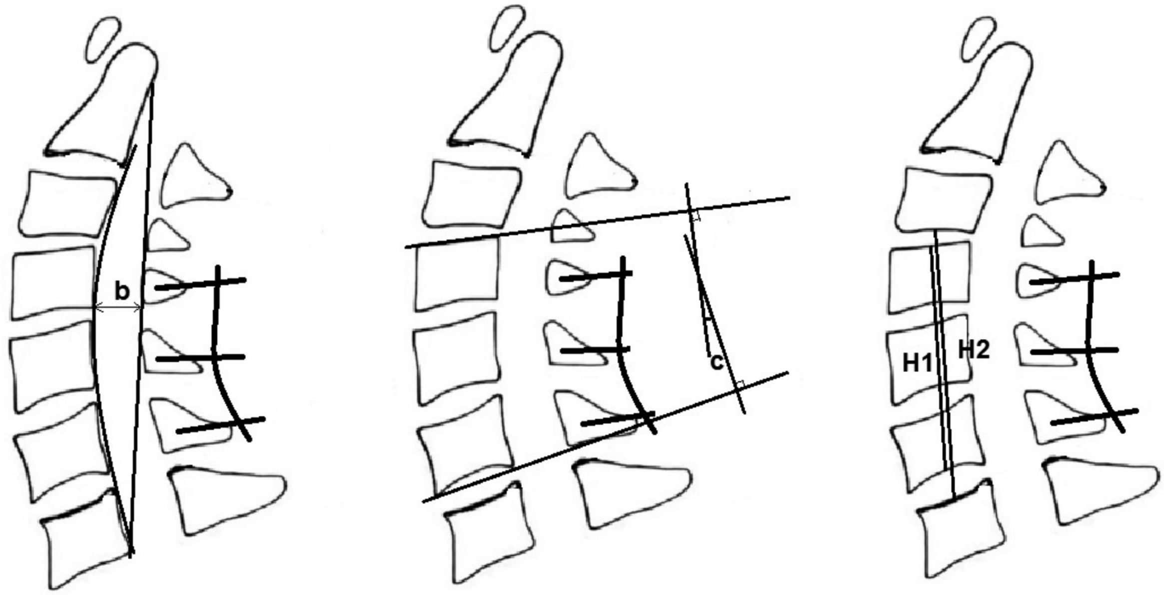

Fig. 1. — Borden value, Cobb's method, Disc space height **(H1)**, inter-vertebral space height **(H2)**. (A) Calculation of the Borden value **(b)**. A straight line is drawn from the superior posterior aspect of the odontoid process of the second cervical vertebra to the posterior inferior aspect of the body of the seventh cervical vertebra. Another line is traced along the posterior aspect of the intervening cervical vertebral bodies. The line b intersects the first line perpendicularly at the point of greatest distance between the two lines. The length of line b recorded in millimeters is the depth of the cervical lordosis (Borden AG, 1960). (B) Cobb's method for measuring cervical lordosis. The cervical lordotic angle is measured according to Cobb's method on a lateral neutral radiograph: the angle **(c)** is formed by the two lines perpendicular to the two lines parallel to the inferior endplates of the fixed vertebral bodies. (C) Disc space height **(H1)** is the height of the fixed vertebral bodies; inter-vertebral space height **(H2)** is the height between the adjacent endplates to the fixed sections.

included both transverse and sagittal T2-weighted high-intensity signal in MRI images.

Posterior cervical laminectomies and fusions were performed in both groups as usual, and attempts were made to realign the local kyphosis using a posterior screw-rod system. A standard posterior approach was employed, with a midline incision created to expose the targeted cervical laminae from the caudal to the cranial edge and extended laterally for complete exposure of the dorsal cortex of the bilateral facet joints. Each spinous process and excised lamina was removed and cut into fragments for grafting. Following complete decompression of the neural elements, a procedure involving lateral mass screw and rod instrumentation was performed. Bilateral facet joints were filled with autologous bone fragments. During the posterior approach, electromyography was used to record somatosensory evoked potentials (SSEP). After staying in bed for the first few days after surgery, patients were then allowed to stand and walk with a Miami neck collar.

The patients were recorded clinically and radiographically with X ray and MRI at pre-operative, immediate postoperative, three-month postoperative and final postoperative follow-up intervals. Neurologic conditions were assessed to evaluate the extent of neurological functional improvement using the scoring system developed by the Japanese Orthopedic Association (JOA). Functional improvements in JOA scores were expressed as the recovery rate (RR) (Hirabayashi K, 1981). The RR was determined as follows: RR (%) = (postoperative JOA score – preoperative JOA score)/(normal functional score – preoperative JOA score) 100. The RR for each patient was classified into four grades: >75% was categorized as excellent for activities of daily living, 50-74% was categorized as good, 25-49% was categorized as fair, and <24% was categorized as poor. The

Table I. — Demographic and primary clinical patient data

Patients	Range and/or Value		
Age (year)	41–78, 58.70±10.30		
Gender (male/female)	43/13		
Duration of symptoms (months)	6–108, 25.16 ±32.06		
Follow-up period (months)	12–69, 25.50 ±12.67		
Pre-/postoperative JOA score	9.77 ± 1.59/13.51 ± 1.71		
JOA Effective / excellent or good rate (%)	92.9 / 67.9	Signal(-) 95.1 / 85.4	Signal(+) 86.7 / 20.0

Borden values, Cobb angles, disc space heights, and adjacent disc space heights of the cervical spine were further measured at immediate postoperative, three-month postoperative, and final postoperative follow-ups to assess the therapeutic efficacy of the operation (Figure 1).

Results were analyzed using SPSS Statistics, Version 18.0 (SPSS Inc., Chicago, IL, USA). The multifactorial effects of variables were studied. The one-way ANOVA tests were used for analyzing the differences between each time-point in the Borden values, Cobb angles, disc space heights, and adjacent disc space heights of the cervical spine. For nonparametric analysis, Mann-Whitney U tests were used to examine the JOA RR differences between the signal (+) and signal (-) groups. For all tests, p values <0.05 were considered significant.

RESULTS

There were 43 men and 13 women in this study whose mean age at the time of surgery was 58.70 years (range 41-78 years). To overcome the limitations of medical records, all 56 patients included in this study willingly participated in a final follow-up interview about their postoperative status. The final follow-up evaluations were conducted at least 12 months after the surgery (25.5 months on average, ranging from 12 to 69 months). The mean postoperative JOA score at the final follow-up (13.51 ± 1.71 points) was significantly higher ($p < 0.05$) than the mean preoperative JOA score (9.77 ± 1.59 points). The majority of patients (52/56; 92.9%) were found to have excellent, good, or fair RR scores. The percentage of 56 patients with an excellent or good RR was 67.9%.

Among the 41 cases in the spinal cord signal (-) group, 7, 28, 4, and 2 were evaluated as having excellent, good, fair, and poor RRs, respectively. The effective rate was 95.1% and the percentage of patients with an excellent or good RR was 85.4%. While no case was assessed as having an excellent RR among the 15 cases in the spinal cord signal (+) group, 3, 10, and 2 were identified as having good, fair, and poor RRs, respectively, with an effective rate of 86.7%. The percentage of patients in this group with an excellent or good RR was 20.0%. Among the 56 patients in this study, CSM continued to develop in two cases (one in the signal (-) group and the other in the signal (+) group), whereas disease progression stopped in the other 54 patients (Table I).

The results of a rank-sum test (Mann-Whitney U test) revealed a significant difference in the RR, which is based on JOA scores, between the signal (+) and signal (-) groups ($p < 0.05$) (Table II).

The Borden value, Cobb angle, disc space height, and inter-vertebral space height of cervical spine data from the four different time points described above met the requirements of homogeneity of variance for statistical analysis. The results of the analysis of variance showed that the Borden values and Cobb angles collected were statistically

Table II. — JOA recovery rate between the signal (+) and signal (-) groups

	N	Mean Rank	Sum of Ranks
Signa l(-)	41	26.59	1090.00
Signal (+)	15	11.67	175.00
p		0.000*	

* Statistically significant difference as assessed by a Mann-Whitney U test

Table III. — Radiological outcome of the patients.

Radiologic index	Value	*p*
Pre-operative/immediate postoperative/3-month postoperative/final follow-up Borden value (mm)	2.55/4.59/4.78/4.83	0.000*
Cobb angle (degree)	9.67/14.29/14.58/14.68	0.000*
Disc space heights (mm)	76.79/81.44/81.89/82.16	0.764
Inter-vertebral space heights (mm)	6.48/6.56/6.56/6.61	0.272

*Statistically significant difference

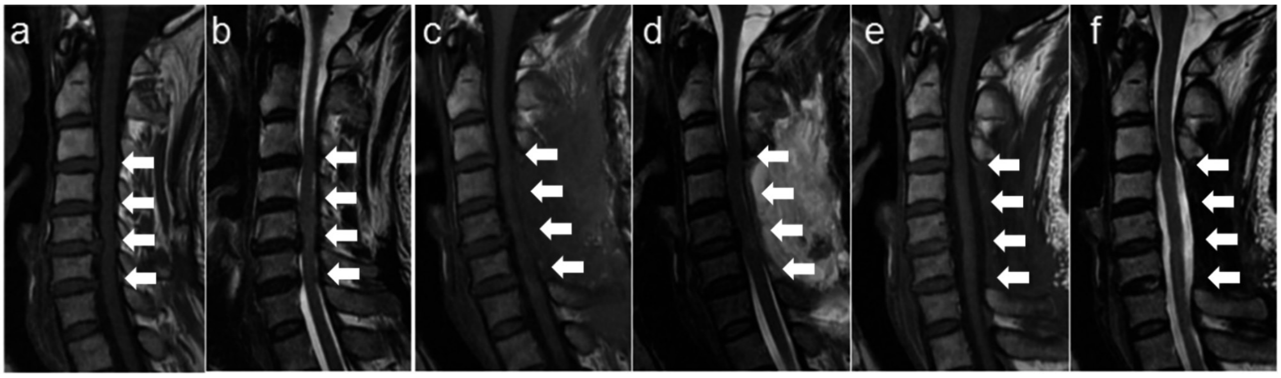

Fig. 2. — Pre- and postoperative MRI results from a 55-year-old man with multilevel cervical canal stenosis. **(a, b)** Preoperative sagittal views from the patient's MRI results show the cervical spinal cord compressed by degenerative disc herniation at C3-4, C4-5, C5-6, and C6-7 with four-level hypertrophic ligamentum flavum. **(c–f)** 1-week postoperative **(c, d)** and 12-month postoperative **(e, f)** sagittal MRI views demonstrate satisfactory decompression of the spinal cord. The dural sac has expanded significantly, and no restenosis is observed.

different between time points ($p < 0.05$), whereas the disc space heights and inter-vertebral space heights were found to be not significantly different between these time points ($p > 0.05$). Further analysis of pairwise comparison revealed that preoperative Borden values and Cobb angles were significantly different from those collected at immediate postoperative, 3-month postoperative, and final postoperative follow-up intervals ($p < 0.05$). However, no significant differences were identified among the postoperative Borden values and Cobb angles at these three later time points ($p > 0.05$) (Table III).

MRI data from one year after surgery also showed a satisfactory expansion of the spinal cord, and no significant concave defect on the dorsal side of the dural sac between the reconstructed levels was found in any patient (Figure 2).

No severe surgical complications, such as spinal cord injury or leakage of cerebrospinal fluid, occurred. No patients had implant failure, such as screw loosening, displacement, or rupture, and no patients reported severe neck pain that interfered with activities of daily living. Four patients were noted to have C5 radiculopathy, and these patients recovered after symptomatic treatment. Infection was found in one patient, and this patient recovered after a revision of the wound and the application of a sensitive antibiotic treatment.

DISCUSSION

MCSM is frequently encountered in clinical practice and leads to a declining quality of the patient's life. Usually the pathophysiology of CSM includes direct dorsal compression. Thus, it is necessary to expand the spinal canal and resect the ligamentum flavum to reduce posterior compression.

Previous report found that there is no apparent difference in the neural function recovery rate between MCSM patients treated with anterior cervical decompression and fusion and those treated with posterior laminoplasty. However, the complication and reoperation rates following anterior cervical surgery were reported to be significantly higher than those following posterior surgery (Liu X, 2014). Decompression via posterior laminoplasty and cervical lordosis alignment allows the spinal cord to float away from ventral compression, thus permitting an indirect decompression of the whole cervical cord. In our department, to avoid restenosis, we recommend a posterior laminectomy-plus-fusion procedure for patients with cervical instability (Park AE, 2004 ; Rhee JM, 2008 ; Gok B, 2009). As demonstrated by the significantly increased JOA scores of the patients in this study, this approach yields a satisfactory clinical outcome. Furthermore, in this study, the overall neurological functional improvement rate in patients receiving this treatment was 92.9%, and the percentage of patients with an excellent or good RR was 67.9%.

The results from our analysis of variance show that the Borden values and Cobb angles measured before the operation were significantly different than those from the three postoperative time points. This finding indicates that the cervical curvature still maintained a certain recovery degree after the surgery. Meanwhile, disc space heights and inter-vertebral space heights were not found to be significantly different between any of the four time points. Sagittal balance in the spinal column has become an important and recognized goal in any spinal reconstructive surgical procedure (Johnson JP, 2004). Therefore, the maintenance of good cervical spine curvature likely played a positive role in the recovery of neural function and reduced the axial symptoms. The stability of the cervical curvature of the segmental function was active, which can prevent disease progression, and obvious signs of degeneration were not found in the adjacent segments.

The role of MRI has increased, providing the possibility of a completely non-invasive diagnosis. Intramedullary spinal cord signal intensity observed via MRI might indicate edema, inflammation, vascular ischemia, gliosis, or myelomalacia of the spinal cord (Morimoto T, 1996 ; Nilsson P, 2007). Intramedullary signal changes in T2-weighted MRI are frequently found in patients with cervical compressive myelopathy. Yukawa(Yukawa Y, 2007) reported that an MRI with high intramedullary signal intensity is an indicator of a poor prognosis. In our study, clinical outcomes were significantly worse for patients whose MR images demonstrated high intramedullary signal intensities. Based on our results, posterior decompressive surgery might not significantly improve the myelopathic symptoms of patients with severe preoperative high signal intensity in the spinal cord. Higher signal intensities on preoperative T2-weighted MR images were associated with an increased risk of poor improvement after decompressive surgery. Our study has identified an association between intramedullary signal intensity and surgical outcomes following the surgical treatment of MCSM.

Postoperative C5 nerve palsy is a possible complication of cervical decompression procedures. The average incidence of postoperative C5 palsy following cervical decompression procedures is known to be 8.3% (range 3.2-28.6%) (Takemitsu M, 2008 ; Sakaura H, 2003). The exact pathogenesis of C5 palsy remains unclear; possible causes include nerve root injury and segmental spinal cord disorders (Chen G, 2012). Radcliff KE *et al.* reported that postoperative C5 nerve palsy might be due to a posterior drift of the spinal cord that is related to wide decompression (Radcliff KE, 2014). In our study, four of the 56 patients (7.1%) developed postoperative C5 palsy. The incidence of C5 palsy in this study is similar to that reported by other researchers (Minoda Y, 2003).

Despite today's advances in sterile technique and antibiotic treatment, infection is a devastating possible complication for patients receiving posterior cervical spine surgery, with consequences ranging from skin infection to advanced osteomyelitis of the spine. It is estimated that the incidence of infection is between 0% and 18% (Heller JG, 1994). *Staphylococcus aureus* is the predominant pathogen in these cases, occurring in 28% of all positive cultures in a previous study. The other organisms commonly cultured following posterior cervical spine surgery include Pseudomonas aeruginosa, MRSA, and Escherichia coli (Cebrián

Parra JL, 2012). Patients with these complications require at least one reoperation for wound washout and debridement, and, sometimes, removal of the implant is required.

There are several limitations of this study, for instance, its retrospectivity, the 24% lost for follow-up, the high percentage of signal - patients. Further comprehensive and extended studies will be performed to establish and explain the clinical outcomes.

CONCLUSIONS

Posterior cervical decompression laminectomy with internal fixation effectively improved the overall neurological functions in both groups. However, the improvement rate of the signal (-) group was higher than that of the signal (+) group. Higher signal intensities on the preoperative T2-weighted MR images were associated with a greater chance of poor improvement after decompressive surgery. At meantime, the surgery provided sustaining stability for the cervical spine that was generally well maintained throughout the whole observation period of this study.

Acknowledgments

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