Original Article

Correlation of imaging characteristics of degenerative cervical myelopathy and the surgical approach with improvement for postoperative neck pain and neural function: a retrospective cohort study

Zhuo Ma[1#], Qiao Ye[2#], Xun Ma[1], Chen Chen[1], Hao-Yu Feng[1], Yan-Nan Zhang[1]

[1]Department of Orthopedic Surgery, Shanxi Bethune Hospital, Shanxi Academy of Medical Sciences, Tongji Shanxi Hospital, Third Hospital of Shanxi Medical University, Taiyuan, China; [2]Third Hospital of Shanxi Medical University, Shanxi Bethune Hospital, Shanxi Academy of Medical Sciences, Tongji Shanxi Hospital, Taiyuan, China

Contributions: (I) Conception and design: Z Ma, X Ma, HY Feng, YN Zhang; (II) Administrative support: X Ma, HY Feng; (III) Provision of study materials or patients: X Ma, HY Feng, C Chen; (IV) Collection and assembly of data: Z Ma, Q Ye, YN Zhang; (V) Data analysis and interpretation: Z Ma, Q Ye; (VI) Manuscript writing: All authors; (VII) Final approval of manuscript: All authors.

[#]These authors contributed equally to this work.

Correspondence to: Yan-Nan Zhang, MD. Department of Orthopedic Surgery, Shanxi Bethune Hospital, Shanxi Academy of Medical Sciences, Tongji Shanxi Hospital, Third Hospital of Shanxi Medical University, No. 99 of Long-Cheng Street, Taiyuan 030032, China. Email: yannanzhang2020@163.com.

Background: Complex degenerative cervical spondylotic myelopathy (DCM) is characterized by a variety of complex imaging features. The surgical method for DCM remains controversial. This study aimed to examine the correlation between the imaging characteristics of DCM with varying degrees of complexity and the surgical approach and clinical outcome.

Methods: A retrospective cohort study involving retrospective data collection was performed. A total of 139 patients with DCM who underwent surgery between January 2015 and January 2018 in the Orthopedics Department of Shanxi Bethune Hospital were divided into 3 groups according to the complexity of imaging features: 18 patients in the mild group, 66 patients in the moderate group, and 55 patients in the severe group. The Visual Analog Scale (VAS) and Japanese Orthopaedic Association (JOA) scores were used to compare the effects of neck pain and neural function prior to surgery according to the rate of improvement as of the last follow-up. Routine X-ray films were obtained at the follow-up of 3–6 months. The necessity of computed tomography (CT) and magnetic resonance imaging (MRI) examinations was determined based on clinical findings and X-ray images. Analysis of variance (ANOVA) was used to compare groups, the least significant difference (LSD) test was used for multiple comparisons, and the Chi-square test was used to compare classification indicators (imaging manifestations, gender), with $P<0.05$ being statistically significant. Binary logistic regression analysis was performed to determine the primary influencing factors of the JOA recovery rate.

Results: In all three groups, JOA and VAS scores at the final follow-up were significantly higher than those before surgery ($P<0.001$). There were significant differences in the preoperative VAS and JOA scores between any two groups, as well as in the VAS and JOA scores and improvement rates at the last follow-up between the mild group and the moderate group and between the mild group and the severe group ($P<0.001$). Age, preoperative JOA scores, MRI intramedullary hyperintensity signal, and the degree of spinal cord compression were primarily related to the nervous system recovery rate ($P<0.001$).

Conclusions: Age, MRI intramedullary hyperintensity signal, degree of spinal cord compression, and other variables were associated with the improvement of neural function in patients with DCM. Therefore, in addition to the JOA improvement rate or VAS score, additional factors, such as the patient's condition, the improvement in quality of life, and the patient's financial capacity, should be considered in evaluating the improvement of postoperative neck pain and neural function.

Keywords: Cervical spondylotic myelopathy; imaging; Japanese Orthopaedic Association scores (JOA scores); surgical approach

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Introduction

Degenerative cervical myelopathy (DCM) is a disease in which cervical intervertebral disc degeneration causes spinal cord compression or blood supply disorders, consequently impairing the neural function. When conservative treatment fails or neural dysfunction gradually increases, early surgical intervention can restore neural function to its maximum capacity.

Complex DCM involves cervical spondylotic myelopathy with multiple complex imaging characteristics and clinical manifestations of spinal cord compression due to severe cervical vertebral degeneration (1-4). Its main pathological factors include herniated discs (≥3 segments), severe stenosis or fusion of the intervertebral space, large herniated disc with calcification, formation of large osteophytes at the anterior or posterior margin of the cervical vertebra, developmental stenosis of the cervical vertebral canal, cervical vertebral kyphosis or instability; hypertrophy of the yellow ligament, and degeneration of the upper and lower cervical vertebrae. In this study, the complexity of DCM imaging was used to categorize patients into mild, moderate, and severe groups. After the impact of preoperative individual characteristics were accounted for, the general conditions and imaging outcomes of the three groups were analyzed, and it was determined that the neural function recovery rate was primarily influenced by age, preoperative Japanese Orthopaedic Association (JOA) scores, intramedullary hyperintensity signal, and the degree of cervical cord compression. However, the likelihood of functional recovery for these characteristics was small. All these factors were regarded as the most important indicators for determining the function recovery rate in patients with DCM. Surgical strategies were devised based on variables such as the nature of the compression material, location and segment of the oppressor, imaging characteristics, surgeons' experience, the incidence of complications, and costs. Multiple comparisons of the final JOA recovery rates among the three groups revealed that all surgical methods could improve the neural function and neck pain. Generally, posterior surgery causes more damage to the muscles, ligaments, and bone structures behind the cervical spine, and postoperative patients often experience axial pain of the neck (5). In this study, the Visual Analog Scale (VAS) scores of the three groups before surgery and at the last follow-up gradually increased according to the severity of imaging and the proportion of posterior surgery in each group. However, for patients older than 60 years, more complex imaging features indicated a greater severity of injuries to the neural function prior to surgery and less improvement in neural function after surgery. Therefore, the prognosis of the disease can be improved through early diagnosis, prompt treatment, and appropriate surgery.

To prevent deterioration of spinal cord function, the surgical intervention of DCM aims to completely relieve compression, reconstruct the physiological curvature of the cervical vertebra, and restore the biomedical stability of the cervical vertebrae. The surgical method for DCM has been a subject of controversy for some time (6-8). The primary objective of the surgery is to completely relieve spinal cord compression, whereas imaging characteristics are the key to decompression reconstruction technology (9,10). Imaging complexity arises from a variety of imaging factors such as cervical disc degeneration, cervical instability, developmental spinal stenosis, ossification of the ligamentum flava, intramedullary signal changes, and spinal cord compression. Regarding the imaging features of DCM and surgical strategy, Shimokawa *et al.* (11) reported the imaging parameters, characteristics, and implications for optimal treatment and surgical outcomes of ossification of the posterior longitudinal ligament (OPLL) of the cervical spine. Meanwhile, in a study by Harel *et al.* (12), posterior cervical laminectomy and fusion were associated with significantly increased incidences of deep wound infection and wound revision surgery compared with anterior surgery. Findings from Kire *et al.*'s study (13) supported the long-term efficacy of posterior cervical total laminectomy decompression for DCM with a low incidence of clinically significant radiological deterioration. Finally, Cao *et al.* (1) evaluated the imaging scoring criteria for surgical selection in patients with DCM but did not group these patients according to the complexity of the image. In our study, patients were grouped according to the complexity of the imaging characteristics of DCM to examine the correlation of the imaging characteristics and the surgical approach with clinical outcome. We present this article in accordance with the STROBE reporting checklist (available at https://qims.amegroups.com/article/view/10.21037/qims-23-1481/rc).

Methods

General data

A retrospective cohort study involving retrospectively collection data of 139 patients with DCM who were admitted to the Orthopedics Department of Shanxi Bethune Hospital between January 2015 and January 2018 was conducted. Anterior-posterior, neutral, and flexion-extension, and lateral X-rays were performed to evaluate the vertebral space stenosis, developmental spinal stenosis, osteophyte formation, and cervical stability. Sagittal and axial computed tomography (CT) imagings with bone window, soft-tissue window, and three-dimensional (3D) reconstruction were completed to evaluate the degree of disc calcification, osteophyte formation, and ossification of the ligamental flava. Sagittal and axial T2-weighted (T2W) magnetic resonance imaging (MRI) was performed to evaluate the degree of spinal cord compression and intramedullary hypersignal. Patients were divided into three groups based on the preoperative X-ray film, CT imaging, 3D reconstruction, and the complexity of MRI manifestations (2,9). The VAS and JOA scores were used to assess neck pain and neural function before and after surgery, and the JOA improvement rate as the last follow-up was calculated. The general data and imaging characteristics of the three groups were statistically analyzed. This study was conducted in accordance with the Declaration of Helsinki (as revised in 2013) and was approved by the institutional ethics board of Shanxi Bethune Hospital (No. YXLL-2019-93). Informed consent was obtained from all the patients.

Patients were included if they had typical clinical manifestations (e.g., limb numbness and weakness, physiological hyperreflexia, positive pathological sign), were diagnosed with DCM via MRI, and had complete imaging data and at least one of the following imaging features: the loss of intervertebral space height, formation of osteophyte, and diffuse sclerosis of the endplate of the involved level.

Two experienced spinal surgeons with over 20 years of clinical experience evaluated the imaging data of each patient prior to surgery, and a third spinal surgeon was consulted in the event of a disagreement. In this study, the degree of cervical intervertebral disc degeneration, namely the loss of intervertebral space height, osteophyte formation, and diffuse sclerosis of the endplate of the involved level, was observed using the Kettler X-ray criteria (2). The most severely degenerated level and the degree of intervertebral disc degeneration were comprehensively evaluated according to the following scheme: mild, 1–3 points; moderate, 4–6 points; and severe, 7–9 points. The following elements were evaluated based on the cervical vertebral X-ray and CT reconstruction film: cervical instability (lateral film of the cervical vertebra indicating physiological kyphosis and the flexion–extension film indicating intervertebral angular displacement greater than 10° or horizontal displacement greater than 3 mm) (14), degree of intervertebral disc degeneration, presence of developmental spinal stenosis (Pavlov ratio <0.75) (1,5), presence of a herniated disc with calcification, and presence of segmental or continuous ossification of the yellow ligament. The following aspects were evaluated based on the T2W MRI sagittal and axial views: whether the involved herniated disc exceeded one-half of the adjacent vertebra's posterior height and whether there was an intramedullary hyperintensity signal zone (T2 hyperintensity). The MRI axial view was used to determine the following degrees of spinal cord compression (9): mild (compression <1/3), moderate (compression 1/3 to 1/2), and severe (compression >1/2).

Patients with any of the following were excluded from this study: cervical myelopathy with <3 segments (segments were defined via disc space); OPLL; cervical tumors or infections; congenital cervical vertebra malformation; thoracolumbar degenerative disease or other serious systemic diseases; a history of cervical vertebra surgery; and a history of cerebrovascular disease, peripheral neuropathy,

Table 1 Imaging characteristics and surgical procedures in the mild, moderate, and severe groups of patients with DCM

Related factors	Mild group (n=18)	Moderate group (n=66)	Severe group (n=55)	Total (n=139)	χ^2	P
Degree of intervertebral disc degeneration					28.628	<0.001
Mild	2	0	0	2		
Moderate	12	20	12	44		
Severe	4	46	43	93		
Degree of spinal compression					21.584	<0.001
Mild	3	2	0	5		
Moderate	11	23	14	48		
Severe	4	41	41	86		
Cervical instability					13.498	0.001
Yes	4	31	38	73		
No	14	35	17	66		
Intramedullary hyperintensity					5.448	0.066
Yes	4	20	26	50		
No	14	46	29	89		
Developmental stenosis of spinal canal					18.067	<0.001
Yes	2	20	33	55		
No	16	46	22	84		
Surgical procedure					15.874	<0.001
ACDF	6	17	0	23		
ACDF + ACCF	4	11	12	27		
Hybrid	3	1	0	4		
Laminoplasty	5	32	31	68		
Laminectomy with fixation	0	5	12	17		

Based on the preoperative X-ray film, CT imaging, 3D reconstruction, and the complexity of MRI manifestations, patients were divided into three groups: the mild group, the moderate group and the severe group. DCM, degenerative cervical myelopathy; ACDF, anterior cervical discectomy and fusion; ACCF, anterior cervical corpectomy decompression and fusion; CT, computed tomography; MRI, magnetic resonance imaging; 3D, three-dimensional.

or motor neutron disease.

Grouping criteria

Patients were placed in a mild, moderate, or severe group according to imaging characteristics. Patients with the following characteristics were placed into the mild group: (I) simple soft disc herniation with moderate stenosis of the intervertebral space (33% to 66%), (II) mild calcification of the intervertebral disc or formation of a small osteophyte at the posterior margin of the intervertebral space, and (III) intervertebral instability with mild kyphosis (Cobb angle <0°) (14). All 18 patients in this group experienced compression at three segments (*Table 1*).

Patients with the following characteristics were placed into the moderate group: (I) severe stenosis (>66%) of the intervertebral space, (II) the formation of a large osteophyte on the posterior margin of the vertebra, (III) intervertebral instability with moderate kyphosis (Cobb angle of 20–40°) (14), (IV) hypertrophy or ossification of the yellow ligament, and (V) development of stenosis of the cervical spinal canal (15). In this group, 44 patients experienced compression of 3 segments, while 22 patients experienced compression of ≥4 segments (*Table 1*).

Patients with the following characteristics were placed into the severe group: (I) severe stenosis (>66%) or fusion of the intervertebral space, (II) the formation of a large osteophyte or bone bridge at the posterior margin of the vertebra, (III) intervertebral instability with severe kyphosis (Cobb angle >40°) (14), and (IV) upper and lower cervical spine degeneration with spinal cord compression. In this group, 11 patients experienced compression of 3 segments, while 44 patients experienced compression of ≥4 segments (C3–7: 34 patients; C2–7: 6 patients; C1–7: 4 patients) (*Table 1*).

Imaging and neural function determination at the postoperative follow-up

The preoperative and postoperative neck pain and neural function of the three groups were measured using the VAS and JOA scales, and the neural function recovery rate was calculated using the following formula: JOA recovery rate = (postoperative score − preoperative score)/(17 − preoperative score) × 100% (5). After surgery, all patients were examined at 1, 3, 6, 12, and 60 months. Routine X-ray films were taken between 3 and 6 months of follow-up. The necessity of CT and MRI examinations was determined based on clinical findings and X-ray images.

Surgical approach

The surgical approach was determined based on clinical manifestations and preoperative imaging data. Anterior surgery alone cannot relieve the compression of the posterior spinal cord. The principle of posterior surgery is to enlarge the spinal canal diameter and increase the lumen volume. Under the "bowstring effect", the spinal cord is shifted backward to achieve the effect of relieving pressure and restoring normal blood perfusion, and so posterior surgery was adopted. The anterior cervical discectomy and fusion (ACDF), anterior cervical corpectomy decompression and fusion (ACCF), or cervical artificial disc replacement (CADR) combined with ACDF or ACCF (hybrid surgery) was adopted. For the posterior approach, the patients were placed in a prone position with their necks flexed and fixed in the Mayfield framework. An incision was made in the center of the back of the neck. Expansive open-door laminoplasty (LP) or laminectomy (LN) combined with pedicle screw or lateral mass screw fixation [LN + internal fixation (IF)] was then implemented.

Postoperative management

Drainage was performed in patients (with no cerebrospinal fluid leakage) on the third or fourth days after surgery, and their bedtime was determined based on their general conditions. Subsequently, 24–72 hours after surgery, all patients in good condition completed functional exercise with semirigid cervical collar support. The cervical collar support was worn for 1 month by patients who underwent the anterior approach and for 2–3 months by patients who underwent the posterior approach. Patients were instructed to gradually begin to exercise their posterior cervical extensor after removal of the cervical collar support to prevent excessive cervical flexion, extension, and rotation.

Statistical analysis

SPSS 22.0 statistical software (IBM Corp., Armonk, NY, USA) was used to examine the normality and homogeneity of variance of quantitative indicators (age, disease course, preoperative and postoperative VAS and JOA scores, JOA recovery rate as of the last follow-up). The mean ± standard deviation was used for statistical description, analysis of variance (ANOVA) was used to compare groups, the least significant difference (LSD) test was used for multiple comparisons, and the Chi-square test was used to compare classification indicators (imaging manifestations, gender). $P<0.05$ (two-sided test) was considered to be statistically significant. A binary logistic regression analysis was performed to determine the primary influencing factors of the JOA recovery rate.

Results

Patients were divided into three groups based on the preoperative X-ray film, CT imaging, 3D reconstruction, and the complexity of MRI manifestations (2,9): (I) the mild group (18 patients, 10 males and 8 females) had a mean age of 56.6±8.8 years and a mean disease course of 33.2±39.2 months, (II) the moderate group (66 patients, 42 males and 24 females) had a mean age of 61.7±7.6 years and a mean disease course of 40.1±34.7 months, and (III) the severe group (55 patients, 38 males and 17 females) had a mean age of 63.1±7.1 years and a mean disease course of

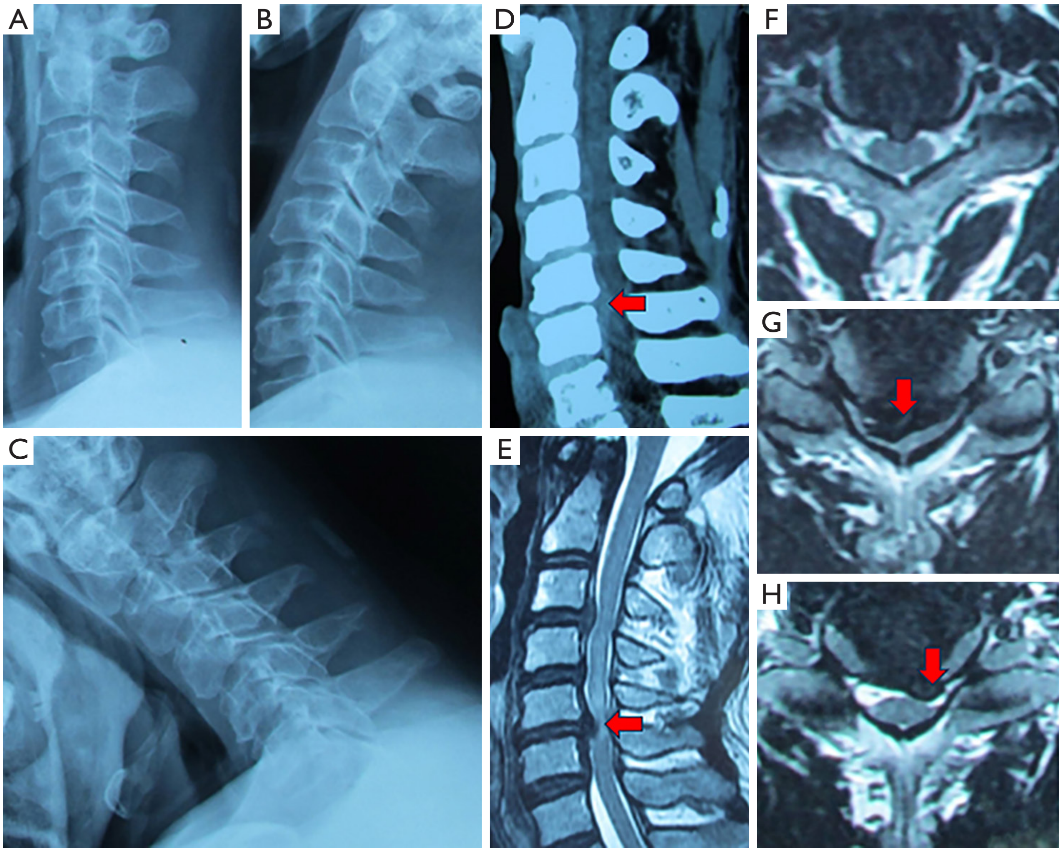

Figure 1 Images from a 61-year-old male in the mild group before undergoing hybrid surgery. (A) The lateral or neutral X-ray revealed a straightened cervical curvature. (B,C) C4–5 and C6–7 intervertebral instability detected via dynamic X-ray imaging. (D) Sagittal CT revealed moderate C5–6 intervertebral space stenosis (arrow). (E-H) Sagittal T2WI and axial MRI revealed disc herniation at the C3–4 and C5–7 vertebrae, as well as spinal cord compression (arrows). CT, computed tomography; T2WI, T2-weighted imaging; MRI, magnetic resonance imaging.

43.4±27.3 months.

According to their medical records, the ages of the 139 patients ranged from 41 to 79 years, and the duration of the disease ranged from 7 to 216 months. All patients were followed up for 5 years after surgery. At the most recent follow-up, no loosening or ruptures of IF were discovered. Sixteen patients developed C5 nerve root paralysis after undergoing the posterior approach; however, their symptoms gradually improved after conservative treatment for 3–6 months.

There were 5 patients with mild spinal cord compression, 48 with moderate spinal cord compression, and 86 with severe spinal cord compression among the 139 patients (9). Regarding treatment, 23 patients were treated with ACDF, 27 with ACDF + ACCF, 4 with CADR combined with ACDF or ACCF (hybrid surgery), 68 with LP, and 17 with laminectomy with fixation. The imaging results and distribution of surgical techniques are presented in *Table 1*, and typical cases in each group are depicted in *Figures 1-6*.

As shown in *Table 2*, there were no statistically significant differences among the three groups in terms of gender ($P=0.561$) or disease progression ($P=0.509$), and the mean age of the moderate and severe groups was higher than that of the mild group ($P=0.007$). The JOA scores before surgery were 10.278±1.406, 6.894±0.947, and 6.109±0.832 for the mild, moderate, and severe groups, respectively ($F=125.103$, $P<0.001$), and at the last follow-up, the scores were 14.833±1.403, 13.182±1.006, and 12.564±0.958, respectively ($F=35.554$, $P<0.001$); the final JOA recovery rates were 69.083%±10.117%, 62.308%±8.908%, and 59.360%±7.450%, respectively ($F=8.883$, $P<0.001$); the VAS scores before surgery were 4.11±0.963, 5.21±0.920,

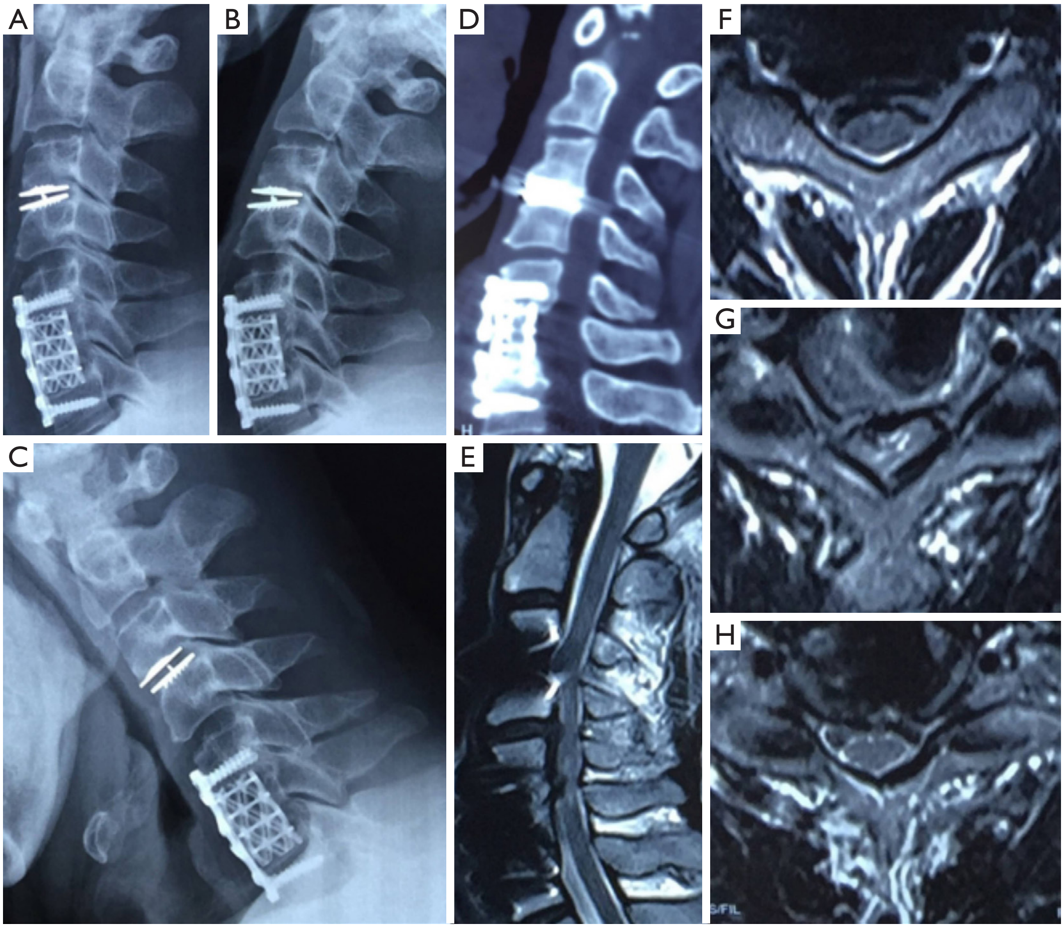

Figure 2 Images from a 61-year-old male in the mild group at the last follow-up after hybrid surgery. (A-D) The cervical curvature, range of motion, and position of the prosthesis were all in good condition on lateral or neutral dynamic X-rays and sagittal CT scans. (E-H) Sagittal T2WI and axial MRI demonstrated complete spinal cord decompression. CT, computed tomography; T2WI, T2-weighted imaging; MRI, magnetic resonance imaging.

and 5.89±0.936, respectively (F=25.872, P<0.001), and at the last follow-up, they were 0.61±0.608, 1.33±0.664, and 1.64±0.704, respectively (F=15.814, P<0.001); the VAS improvement rates were −3.50±0.514, −3.88±0.621, and −4.25±0.799, respectively (F=9.534, P<0.001) (*Tables 3,4*). At the last follow-up, neck pain and neural function were improved in all three groups as compared to before surgery (P<0.05). Multiple comparisons revealed statistically significant differences in VAS scores before surgery and at the last follow-up in all groups and between any two groups after surgery. The JOA recovery rates showed statistically significant differences at the last follow-up between the mild and moderate groups and between the mild and severe groups (P<0.05; *Tables 5,6*).

The step-back method was used to conduct a binary logistic regression analysis with the final JOA recovery rate at the follow-up as the dependent variable and age, preoperative JOA score, degree of spinal cord compression, degree of intervertebral disc degeneration, intramedullary hyperintensity signal, developmental stenosis of the cervical spinal canal, and surgery as the covariates. The distribution of variables is presented in *Table 7*, and the results of the analysis are shown in *Table 8*. According to the results, patients under 60 years of age had higher JOA recovery rates than did those older than 60 years. The recovery rate of patients with a preoperative JOA score of 6–7 was 66.747 times greater than that of those with a preoperative JOA score below 6. The JOA recovery rate of patients with intramedullary hyperintensity signal on preoperative MRI was 0.151 times greater than that of patients without intramedullary

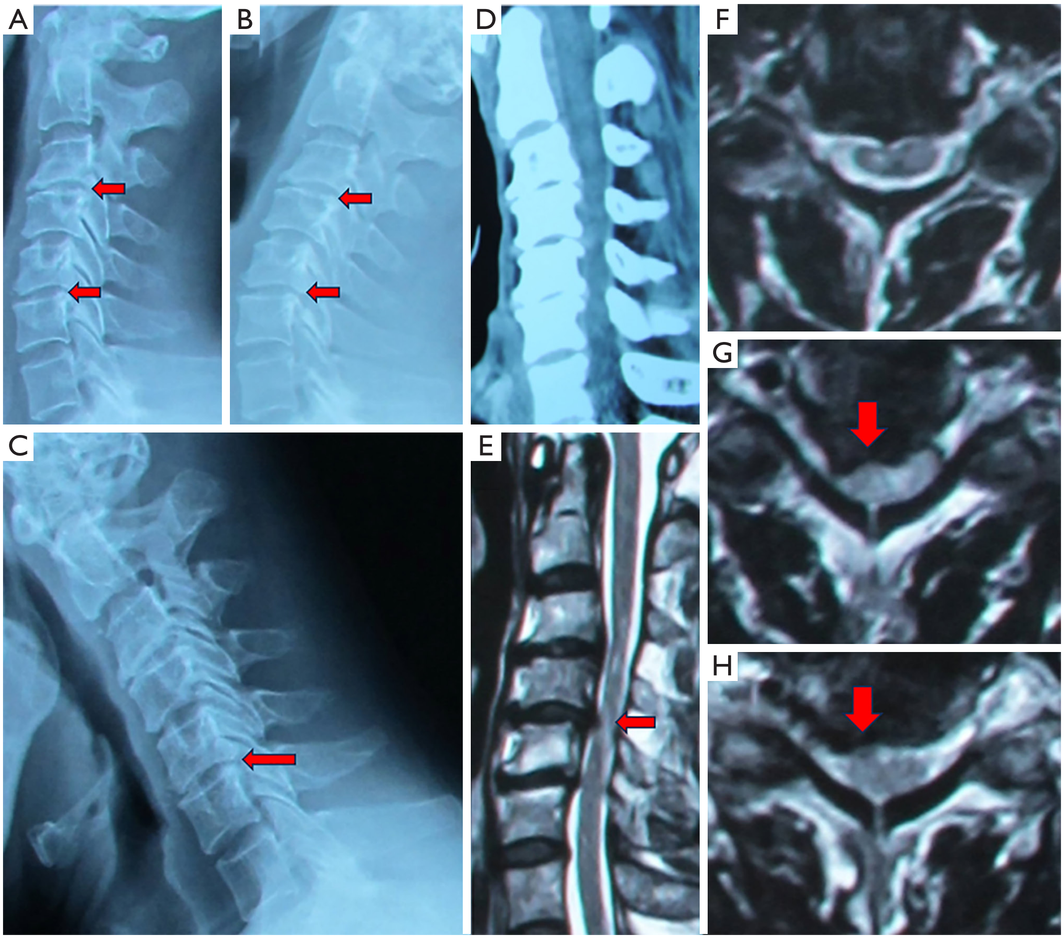

Figure 3 Images from a 49-year-old male in the moderate group before ACDF plus ACCF surgery. (A-C) Lateral, neutral, and dynamic X-rays revealed intervertebral instability at the C2–3 and C5–6 level with kyphosis (arrows). (D) Sagittal CT revealed severe stenosis of the C5–6 intervertebral space and osteophyte formation at the posterior margin of the vertebrae. (E-H) Sagittal T2WI revealed intramedullary hyperintensity signal at the C3–4 vertebrae, and axial MRI showed C3–6 disc herniation and spinal cord compression at the C3–6 vertebrae (arrows). ACDF, anterior cervical discectomy and fusion; ACCF, anterior cervical corpectomy decompression and fusion; CT, computed tomography; T2WI, T2-weighted imaging; MRI, magnetic resonance imaging.

hyperintensity signal in preoperative MRI. The JOA recovery rate of patients with severe spinal cord compression on preoperative MRI was 0.014 times greater than that of patients with mild or moderate spinal cord compression. There was no correlation between the JOA recovery rate and the degree of intervertebral disc degeneration (P=0.387), developmental stenosis of the cervical vertebral canal (P=0.678), or surgical methods (P=0.556).

Discussion

Several studies indicate that the anterior and posterior approaches for DCM yield comparable neural system improvement rates (6,7,16) and that each has its advantages and disadvantages, with no clear superiority (16,17). In this study, most patients in the mild and moderate groups were treated via the anterior approach that included fusion and direct decompression without fusion. Although discectomy, intervertebral disc decompression, and fusion remain standard and conventional procedures, their relative efficacy and safety are controversial (15,18). In their study, Liu *et al.* (15) found that the fusion rate and complication rate in the ACDF, ACCF, and ACDF + ACCF groups were comparable in the 286 patients with DCM, whereas the nonfusion rate and complication rate remained the highest in the ACCF group. However, further research is

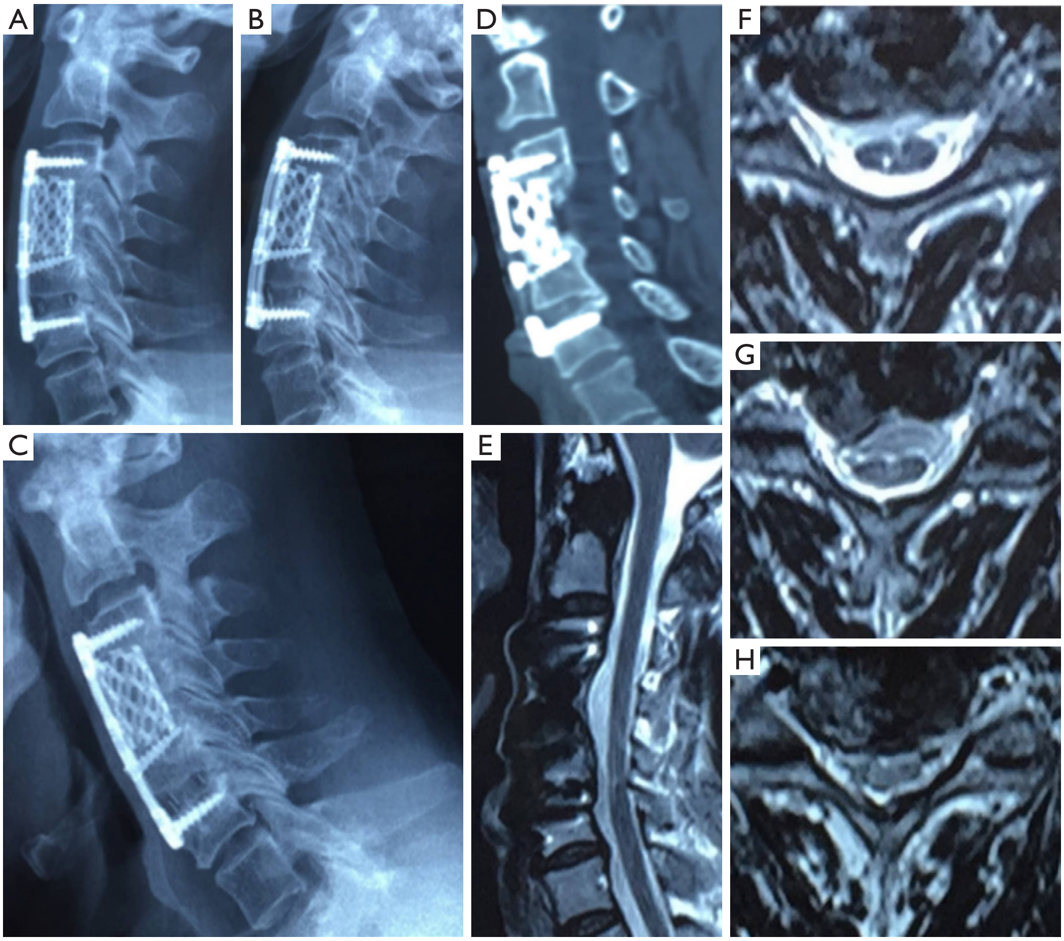

Figure 4 Images from a 49-year-old male in the moderate group at the last follow-up after ACDF plus ACCF surgery. (A-D) Lateral or neutral dynamic X-rays and sagittal CT images revealed the recovery of the cervical spine's physiological curvature, and the prosthesis was in good position. (E-H) Sagittal T2WI and axial MRI demonstrated complete spinal cord decompression. ACDF, anterior cervical discectomy and fusion; ACCF, anterior cervical corpectomy decompression and fusion; CT, computed tomography; T2WI, T2-weighted imaging; MRI, magnetic resonance imaging.

required to establish the superiority of cervical anterior decompression and fusion. Depending on the characteristics of each segment, fusion and nonfusion hybrid surgical approaches may be used to treat continuous multisegment lesions. CADR is feasible for segments with only mild herniated disc degeneration, whereas fusion can be performed for unstable segments with severe degeneration to maximally preserve cervical vertebral motion (18-20). This not only prevents the decrease in the cervical vertebral range of motion and degeneration of adjacent segments after fusion but also solves the problem of the limited application of CADR (18-20). Despite this, indications and contraindications for surgical procedures must be strictly regulated. In general, the posterior approach is used to treat degeneration of multisegmental cervical vertebrae (17), as the anterior approach is technically challenging and may cause spinal cord damage. In the event of segmental instability, posterior lateral mass or pedicle screw fixation may be used (21,22). Although studies have reported patients who have clinically good outcomes with anterior segmental decompression with preservation of a portion of the posterior vertebral wall (23,24), the MRI and clinical observation of patients undergoing the posterior approach suggest that the spinal cord is also completely decompressed under the anterior approach. For some patients who develop complications such as nerve root paralysis and axial symptoms following surgery, rehabilitation measures can gradually alleviate these symptoms. A one-stage surgery

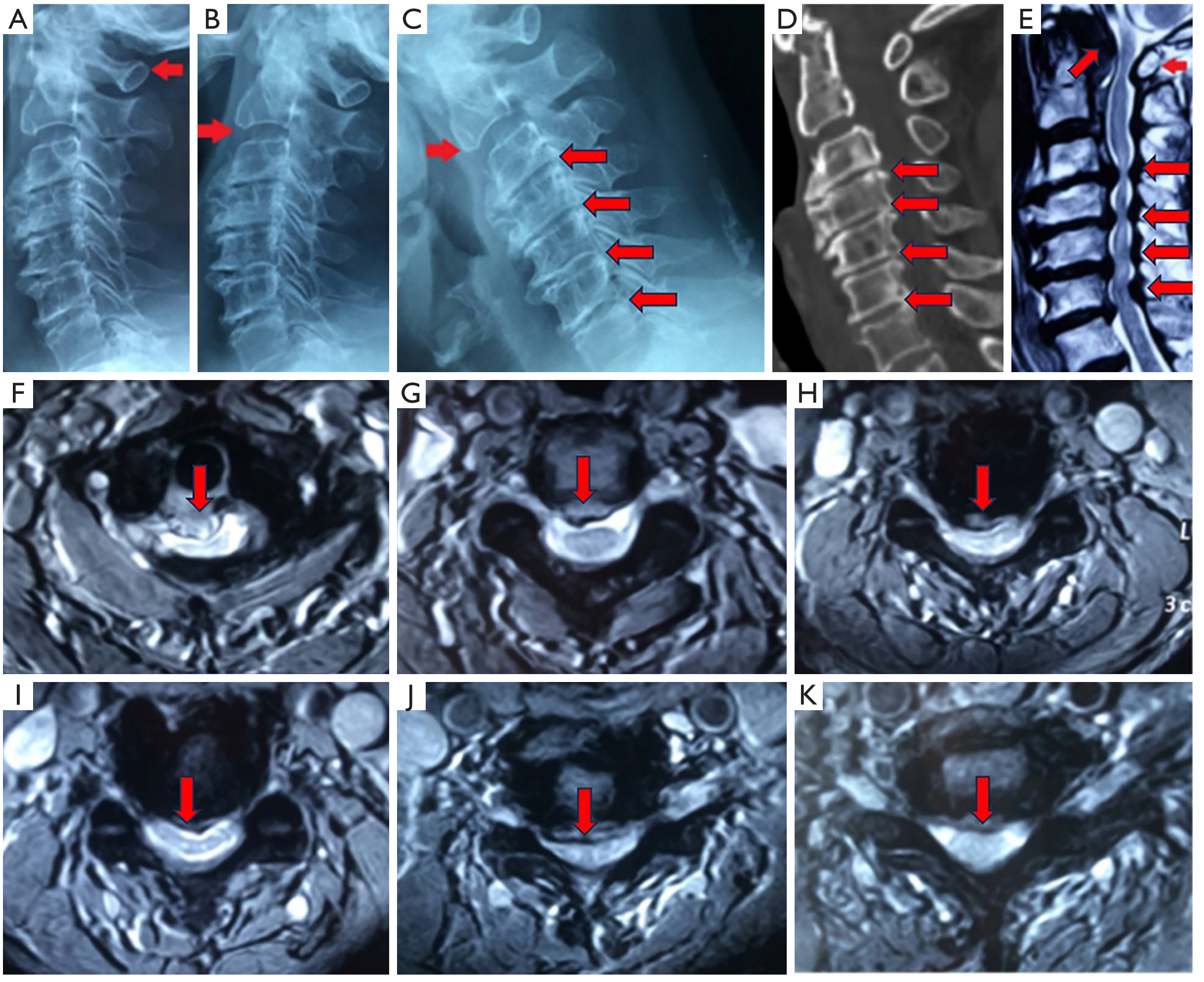

Figure 5 Images from a 74-year-old female in the severe group before laminectomy. (A) The lateral or neutral X-ray revealed dysgenesis of the posterior arch of the atlas (arrow) as well as anterior displacement of the posterior arch. (B,C) Dynamic X-ray revealed C2–3 intervertebral instability (arrows). (D) Sagittal CT revealed severe stenosis and hyperostosis of the C3–6 intervertebral space (arrows). (E) Sagittal T2WI demonstrated hypertrophy of the transverse ligament of the atlas, anterior displacement of the posterior arch of the atlas (arrows), compression of the anterior and posterior spinal cord margins at the C1 and C3–7 vertebrae, and intramedullary hyperintensity signals at the corresponding level. (F-K) Axial MRI demonstrated obvious horizontal spinal cord compression at the C1–7 vertebrae (arrows). CT, computed tomography; T2WI, T2-weighted imaging; MRI, magnetic resonance imaging.

combining anterior and posterior approaches is considered safe and effective for patients with complex DCM (25,26), but it is relatively more costly and traumatic. In most cases, anterior or posterior decompression performed in a single stage is effective and satisfactory. Poorly responding patients must be observed for more than 6 months and may require the two-stage approach. In our study, one patient developed a deep wound hematoma within 24 hours after undergoing the anterior approach, which manifested as dyspnea and wound swelling. After the hematoma was removed and patient's symptom relieved, a complete wound incision was performed at the bedside to flush and seal the wound drainage. The patient was then transported to the operating room for wound flushing and drainage sealing. Two patients with leakage of cerebrospinal fluid after LP and one patient with leakage of cerebrospinal fluid after ACDF + ACCF were kept in a supine position and given antibiotics, and constant pressure drainage was conducted for 1 week. The drainage tube was then removed, and the incision was dressed and compressed. The wound

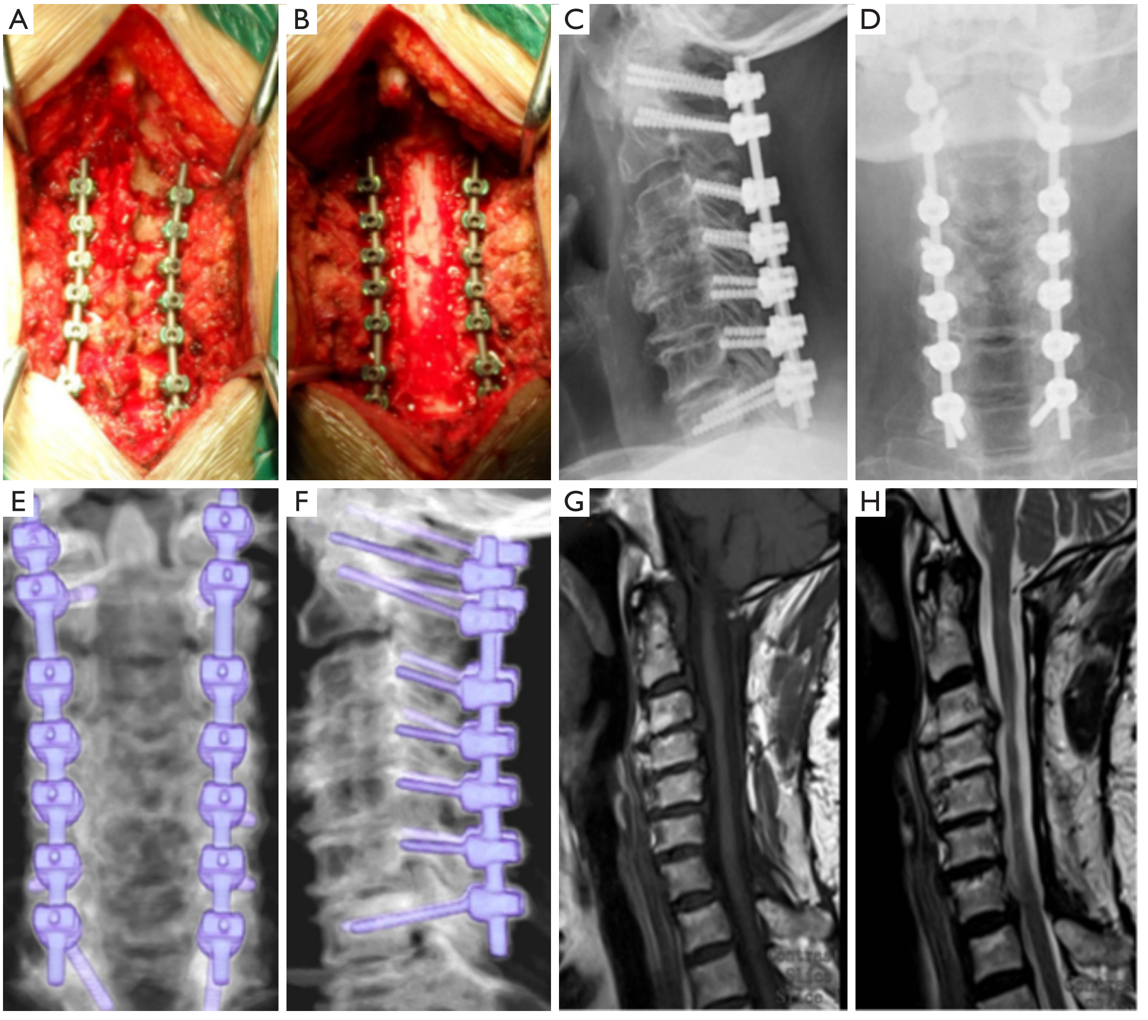

Figure 6 Images from a 74-year-old female in the severe group during laminectomy and at the last follow-up. (A,B) The screw-rod system was in satisfactory position during surgery, and the dural sac was exposed after laminectomy and decompression of the C1–7 vertebrae. (C-F) Anteroposterior and lateral X-rays, along with 3D reconstruction CT, revealed that the implants were in a satisfactory position. (G,H) Sagittal T1WI demonstrated complete decompression of the C1–7 spinal cord, while T2WI demonstrated an intramedullary hyperintense signal. 3D, three-dimensional; CT, computed tomography; T1WI, T1-weighted imaging; T2WI, T2-weighted imaging.

Table 2 Comparison of general data among the mild, moderate, and severe groups of patients with DCM

Variable	Mild	Moderate	Severe	χ^2/F	P
Male-to-female ratio	10/8	42/24	38/17	1.157	0.561
Age (years)	56.6±8.8	61.7±7.6	63.1±7.1	5.131	0.007
Course of disease (months)	33.2±39.2	40.1±34.7	43.4±27.3	0.678	0.509

The data are presented as the mean ± standard deviation. DCM, degenerative cervical myelopathy.

was completely healed upon discharge. Three patients experienced hoarseness following an anterior approach, which resolved after 3–6 months. Moreover, 24 patients developed axial symptoms after LP, which were gradually alleviated by symptomatic treatment for 6–24 months. Consequently, individual selection of surgical strategies and

Table 3 Comparison of preoperative JOA score and JOA recovery rate at final follow-up among the mild, moderate, and severe groups

Variable	Mild	Moderate	Severe	F	P
Preoperative JOA score (point)	10.278±1.406	6.894±0.947	6.109±0.832	125.103	<0.001
Final JOA score (point)	14.833±1.403	13.182±1.006	12.564±0.958	35.554	<0.001
Final JOA recovery rate (%)	69.083±10.117	62.308±8.908	59.360±7.450	8.883	<0.001

The data are presented as the mean ± standard deviation. JOA, Japanese Orthopaedic Association.

Table 4 Comparison of preoperative VAS score and final follow-up VAS score among the mild, moderate, and severe groups

Variable	Mild	Moderate	Severe	F	P
Preoperative VAS score (point)	4.11±0.963	5.21±0.920	5.89±0.936	25.872	<0.001
Final VAS score (point)	0.61±0.608	1.33±0.664	1.64±0.704	15.814	<0.001
VAS improvement	−3.50±0.514	−3.88±0.621	−4.25±0.799	9.534	<0.001

The data are presented as the mean ± standard deviation. VAS, Visual Analog Scale.

Table 5 Multiple comparisons of preoperative, final follow-up JOA score, and JOA recovery rate among the mild, moderate, and severe groups

Variable	Group	Average deviation	95% CI		Standard error	P
			Lower limit	Upper limit		
Preoperative JOA score	Moderate (*vs*. mild)	3.3838	2.871	3.896	0.2592	<0.001
	Severe (*vs*. mild)	4.1678	3.645	4.692	0.2647	<0.001
	Mild (*vs*. moderate)	−3.3838	−3.896	2.871	0.2592	<0.001
	Severe (*vs*. moderate)	0.7848	0.433	1.137	0.178	<0.001
	Mild (*vs*. severe)	−4.1687	−4.692	−3.645	0.2647	<0.001
	Moderate (*vs*. severe)	−0.7848	−1.137	−0.433	0.178	<0.001
Final follow-up JOA score	Moderate (*vs*. mild)	1.6515	1.13	2.173	0.2638	<0.001
	Severe (*vs*. mild)	2.2697	1.737	2.802	0.2694	<0.001
	Mild (*vs*. moderate)	−1.6515	−2.173	−1.13	0.2638	<0.001
	Severe (*vs*. moderate)	0.6182	0.26	0.976	0.1811	0.001
	Mild (*vs*. severe)	−2.2697	−2.802	−1.737	0.2694	<0.001
	Moderate (*vs*. severe)	−0.6182	−0.976	−0.26	0.1811	0.001
Final follow-up JOA recovery rate	Moderate (*vs*. mild)	6.7758	2.29	11.261	2.2681	0.003
	Severe (*vs*. mild)	9.7233	5.143	14.304	2.3162	<0.001
	Mild (*vs*. moderate)	−6.7758	−11.261	−2.29	2.2681	0.003
	Severe (*vs*. moderate)	2.9476	−0.132	6.027	1.5573	0.061
	Mild (*vs*. severe)	−9.7233	−14.304	−5.143	2.3162	<0.001
	Moderate (*vs*. severe)	−2.9476	−6.027	0.132	1.5573	0.061

JOA, Japanese Orthopaedic Association; CI, confidence interval.

Table 6 Multiple comparisons of preoperative, final follow-up VAS score, and final VAS improvement among the mild, moderate, and severe groups

Variable	Group	Average deviation	95% CI		Standard error	P
			Lower limit	Upper limit		
Preoperative VAS score	Moderate (*vs*. mild)	−1.101	−1.59	−0.61	0.248	<0.001
	Severe (*vs*. mild)	−1.78	−2.28	−1.28	0.253	<0.001
	Mild (*vs*. moderate)	1.101	0.61	1.59	0.248	<0.001
	Severe (*vs*. moderate)	−0.679	−1.02	−0.34	0.17	<0.001
	Mild (*vs*. severe)	1.78	1.28	2.28	0.253	<0.001
	Moderate (*vs*. severe)	0.679	0.34	1.02	0.17	<0.001
Final follow-up VAS score	Moderate (*vs*. mild)	−0.722	−1.08	−0.37	0.179	<0.001
	Severe (*vs*. mild)	−1.025	−1.39	−0.66	0.183	<0.001
	Mild (*vs*. moderate)	0.722	0.37	1.08	0.179	<0.001
	Severe (*vs*. moderate)	−0.303	−0.55	−0.06	0.123	0.015
	Mild (*vs*. severe)	1.025	0.66	1.39	0.183	<0.001
	Moderate (*vs*. severe)	0.303	0.06	0.55	0.123	0.015
Final follow-up VAS improvement	Moderate (*vs*. mild)	0.379	0.02	0.74	0.182	0.04
	Severe (*vs*. mild)	0.755	0.39	1.12	0.186	<0.001
	Mild (*vs*. moderate)	−0.379	−0.74	−0.02	0.182	0.04
	Severe (*vs*. moderate)	0.376	0.13	0.62	0.125	0.003
	Mild (*vs*. severe)	−0.755	−1.12	−0.39	0.186	<0.001
	Moderate (*vs*. severe)	−0.376	−0.62	−0.13	0.125	0.003

VAS, Visual Analog Scale; CI, confidence interval.

Table 7 Indices and variable assignment

Factors (variable name)	Assignment
Age (x_1)	
60 years	0
≥60 years	1
Preoperative JOA score (x_2)	
<6	0
6–7	1
>7	2
Severity of intervertebral disc degeneration (x_3)	
Mild + moderate	0
Severe	1
Intramedullary hyperintensity (x_4)	
No	0
Yes	1
Developmental stenosis of cervical spinal canal (x_5)	
No	0
Yes	1
Degree of spinal cord compression (x_6)	
Mild + moderate	0
Severe	1
Surgical approach (x_7)	
Anterior approach	0
Posterior approach	1
Grade of JOA recovery rate at final follow-up (x_8)	
<50%	1
≥50%	2

JOA, Japanese Orthopaedic Association.

Table 8 Binary logistic regression analysis results of the JOA improvement rate

Variables	Single factor analysis			Multiple factor analysis		
	OR	95% CI	P	OR	95% CI	P
Age	0.818	0.745–0.899	<0.001	0.761	0.618–0.936	0.01
Preoperative JOA score						
6–7 points	28.636	3.256–251.868	0.002	66.747	3.233–1,378.088	0.007
>7 points	5.973	1.986–17.966	0.001	0.439	0.073–2.649	0.369
Degree of intervertebral disc degeneration	0.28	0.22–0.288	0.001	0.44	0.069–2.822	0.387
Intramedullary hyperintensity	0.186	0.066–0.522	0.001	0.151	0.027–0.848	0.032
Developmental stenosis of cervical spinal canal	0.294	0.109–0.793	0.016	1.438	0.259–7.986	0.678
Degree of spinal cord compression	0.019	0.002–0.144	0.001	0.014	0.001–0.181	0.001
Surgical approach	0.235	0.065–0.846	0.027	0.435	0.027–6.965	0.556

JOA, Japanese Orthopaedic Association; OR, odds ratio; CI, confidence interval.

establishment of a unified standard prognosis evaluation method can help in evaluating individual differences, as DCM may vary in complexity depending on the tolerance to spinal cord compression resulting from each patient's imaging characteristics and clinical manifestations. In addition to imaging standards, therefore, patients' age, clinical manifestations, surgeons' experience and techniques, surgical difficulty, and complications should be considered when selecting the surgical method. In addition to the JOA improvement rate and VAS score, other factors, such as the patients' conditions, the improvement in quality of life, and patients' financial capacity, should be used to evaluate the results (17,21,27).

In the mild group, spinal cord compression mainly originated from the front of the spinal cord, forming multiple indentations of different depths in the front, and thus anterior decompression was adopted. In the moderate and severe groups, in addition to intervertebral disc herniation and osteophyte formation, most patients also had developmental spinal stenosis, hyperplasia of the ligamentum flava, and even simultaneous compression of the anterior and posterior spinal cord of the upper and lower cervical vertebrae. However, there were some limitations in the present study. As we employed a single-center, retrospective study design, there is a need for a prospective, multicenter research to confirm the improvement for postoperative neck pain and neural function as well the outcomes of the medical centers and surgical methods. Additionally, biases were potentially introduced into the study through the interpretation of the images, and the JOA score is a clinician-based metric and can have interrater variability. Although bias was reduced through use of two raters, no interrater observer variability was reported. In addition, the severe group had a greater proportion of older adults, and only ACDF was performed in mild group. Finally, patient grouping only focused on a multilevel compression patients, which is a subgroup of patients. Muhammad *et al.* used a motor test battery from the NIH toolbox to establish DCM severity thresholds. This approach is based on the patient's physical performance in a series of tests rather than on the patient's feelings or thoughts about his or her health. Through this approach, such biases could be avoided in future studies (28).

Conclusions

We found that age, MRI intramedullary hyperintensity signal, degree of spinal cord compression, and other variables were associated with the improvement of neural function in patients with DCM. Therefore, in addition to the JOA improvement rate or VAS score, additional factors, including patients' conditions, the improvement in quality of life, and patients' financial capacity, should be used to evaluate the improvement in postoperative neck pain and neural function.

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Footnote

Reporting Checklist: The authors have completed the STROBE reporting checklist. Available at https://qims.amegroups.com/article/view/10.21037/qims-23-1481/rc

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Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. This study was conducted in accordance with the Declaration of Helsinki (as revised in 2013) and was approved by the institutional ethics board of Shanxi Bethune Hospital (No. YXLL-2019-93). Informed consent was obtained from all patients.

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