Original Article

Classification of cervical disc herniation myelopathy or radiculopathy: a magnetic resonance imaging-based analysis

Shunmin Wang[1,2#], Tianyi Zhao[1#], Dan Han[1#], Xiaonan Zhou[1#], Yuan Wang[1], Feng Zhao[2], Jiangang Shi[1*], Guodong Shi[1*]

[1]Department of Orthopedics, Changzheng Hospital, The Second Military Medical University, Shanghai, China; [2]Department of Orthopedics, 910 Hospital, Quanzhou, China

Contributions: (I) Conception and design: S Wang; (II) Administrative support: S Wang, G Shi, J Shi; (III) Provision of study materials or patients: S Wang, Y Wang, D Han; (IV) Collection and assembly of data: X Zhou, F Zhao, S Wang; (V) Data analysis and interpretation: T Zhao, S Wang; (VI) Manuscript writing: All authors; (VII) Final approval of manuscript: All authors.

[#]These authors contributed equally to this work and should be considered as co-first authors.

[*]These authors contributed equally to this work.

Correspondence to: Guodong Shi, MD; Jiangang Shi, MD. Department of Orthopedics, Changzheng Hospital, The Second Military University, 415 Fengyang Road, Huangpu District, Shanghai 200003, China. Email: shgd008@163.com; chzhshijg@126.com.

Background: Preoperative magnetic resonance imaging (MRI) can clearly show the location and level of disc herniation. When the symptoms are consistent with the Prominent segments, surgical treatment can be indicated. However, the varied extents of the protruding masses in cervical disc herniation (CDH) have been rarely reported. This study aimed to characterize the severity of CDH and to develop a reproducible grading and zoning system for cervical disc degeneration.

Methods: A total of 200 patients who presented with single CDH and underwent MRI/computed tomography (CT) scans were enrolled in this prospective study between 2018 and 2021. A total of 170 cervical discs were graded according to MRI by 3 spine surgeons in a blinded fashion. CDHs were graded 1–3, with regions A–C. All patients with grade 1 and mild C symptoms were excluded. The foramen facet spinal (FFS) classification based on MRI Japanese Orthopedic Association (JOA) scores and the incidence of complications were evaluated and analyzed, and follow-up outcomes were assessed.

Results: Areas 2-A, 2-B, and 1-C had high motor function scores, areas 2-A, 3-A, and 2-AB had high sensory scores, but areas 3-AB and 3-A had low bladder function scores. Areas 3-AB had the most severe symptoms and the lowest scores. Area 1-C showed neurogenic abnormal sensation and higher visual analog scale (VAS) scores. A good/excellent outcome as indicated by the JOA score was 94.70% at 3 months and 92.35% at 1 year in 170 patients. The complication rate was 9.41%. The diagnostic coefficient of the FFS classification was 0.888, $P<0.001$.

Conclusions: The FFS classification is an objective scoring system that can be applied similarly by multiple examiners and is correlated with clinical symptoms.

Keywords: Magnetic resonance imaging (MRI); cervical discectomy; cervical disc herniation; classification

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Introduction

Cervical disc herniation (CDH) is one of the most common degenerative lesions causing radiculopathy and myelopathy (1,2). Early detection and treatment of disc herniation is important to prevent its progression. T2-weighted imaging is commonly used to assess disc degeneration and neurological compression. Black discs are histologically based on the loss of water and proteoglycan content in the disc, which is seen in magnetic resonance imaging (MRI) as reduced disc height and disc herniation (1,3-6). Studies have established classifications based on MRI, in which herniated masses are classified as median, paramedian, and lateral herniations based on their extradiscal location (1,7,8). In general, median or paramedian masses compress the spinal cord, thereby causing myelopathy, whereas lateral masses compress the spinal roots, resulting in radiculopathy. Most severe patients require surgical treatment, usually by anterior decompression and fusion or posterior discectomy.

In such cases, intraoperative removal of the posterior longitudinal ligament reveals a mass located in or penetrating the superficial ligament or even completely displaced into the epidural space (8). MRI can show that the protrusion clearly obliquely protrudes through the ligament. However, few studies have evaluated the relationship between MRI classification of single CDH and clinical symptoms. Therefore, the purpose of this study was to describe a new grading system of CDH, based on MRI or computed tomography (CT), and to assess its reliability regarding clinical symptoms and surgical outcomes.

Methods

Patient population

All patients who presented with a single CDH in the Changzheng Hospital and underwent anterior or posterior discectomy between 2018 and 2021 were prospectively included. The inclusion criteria were as follows: diagnosis confirmed by CT and MRI; clinically, there were spinal cord-type symptoms and/or nerve root-type symptoms, which may have been accompanied by neck pain; conservative treatment had been ineffective for 3 months. The exclusion criteria were as follows: cervical stenosis, ossification of the posterior longitudinal ligament (OPLL). All patients presenting for spine surgery between 2018 and 2021 had symptoms of severe upper extremity pain and/or decreased muscle strength in the neck and shoulder region. Patients underwent preoperative and postoperative plain films, CT, and MRI of the cervical spine. Patients with lateral or anterior disc herniation outside the intervertebral foramen and those with symptoms of vertebral artery compression or sympathetic nerve were excluded. All procedures were performed in the Changzheng Hospital spine surgery department. All patients were evaluated before and after surgery according to Japanese Orthopedic Association (JOA) (9) score and followed up for 1 year, and were determined to be moderate or severe according to the usual subjective criteria based on clinical symptoms and the presence of a large protrusion on MRI. To test its reliability, 60 randomized cervical MRI studies were independently blindly classified by 3 different spine surgeons using a new classification system with a reliability of 89%. Therefore, all patients were retrospectively evaluated on MRI and assessed for overall surgical outcome based on the development of a foramen facet spinal (FFS) score classification.

Transverse imaging was performed at the level of the largest protrusion (thickest and widest) based on the maximum vertebral canal occupancy. Simultaneously, 3 spine surgeons independently reviewed the MRIs of 200 patients with disc herniation and determined that 170 patients had either grade 2 or 3 herniations or severely symptomatic grade C herniations. When 2 spinal surgeons excluded a mild 1C case as inconsistent, it was reclassified by a third surgeon. Each herniation was also classified.

Indications for surgical treatment included severe nerve root compression, finger numbness, spinal cord compression, cervical instability, and lower limb instability, and an MRI revealing severe spinal stenosis. Participants underwent at least 3 months of conservative treatment prior to surgery, and all opted for surgery due to "*gait disturbance*, *varying degrees of spasticity*, *discomfort with thoracoabdominal fasciculations*, *and numbness and pain*". To verify intra- and inter-observer reliability and consistency, 3 experienced surgeons were blinded and independently evaluated the MRIs of all participants. The 3 examiners classified the disc protrusions using the proposed FFS scheme on the MRIs.

Neurological status was assessed by the JOA score. The total motor function, sensory, and bladder function scores were 8, 6, and 3, respectively. The scores of each group were statistically analyzed separately. Hirabayashi *et al.* (10) proposed the following formula for the evaluation of the success rate of surgical procedures: improvement rate (%) = (postoperative score – preoperative score]/(17 – preoperative score) ×100%. A recovery rate of <25% is considered fair, 25–50% is considered poor, 50–75% is good, and >75% is excellent.

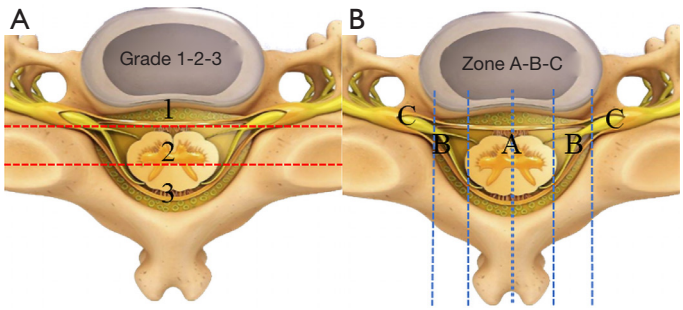

Figure 1 Grading the lesions for size (A) and zoning the spinal canal for location (B).

The visual analog scale (VAS) (11), arm and neck pain questionnaires, were applied to assess the severity of nerve root involvement. The scale comprises 10 equal points using a ruler: 0 indicates no pain, 1–3 indicates mild pain, 4–6 indicates moderate pain, and 7–10 indicates severe pain.

FFS classification

Hypertrophy of the ligamentum flavum (compression due to ligamentous hypertrophy), spinal stenosis, and ligamentous ossification should be excluded. Since the mark with the partition line is based on 3 key anatomical structures, it is a task involving simple memory, so its first letter is taken as the full name.

The FFS classification takes into account the prominence and its location within the various constraints imposed by the local anatomy. It uses the posterior line of the intervertebral foramen as a reference point for measuring herniations and serves as a preoperative plan for the surgeon to accurately predict the difficulty of surgery and the extent of decompressive exploration. Thus, the size and location of the herniation is measured at the level of maximum protrusion and compression in cross-section. The posterior line of the foramen is defined as the line connecting the posterior margins of the foramina at the nerve root outlets on both sides, and the midline of the articular eminence is defined as the line connecting the centers of the articular eminences on both sides (upper and lower may be integral).

The FFS classification scheme describes cervical disc protrusions in terms of both posterior protrusion and mediolateral location. The numeric grade indicates the degree of posterior protrusion (1= when the herniation remains before the foraminal line, 2= when the herniation remains before the line between the foraminal line and the midline of the articular process, 3= when the herniation remains after the midline of the articular process; see *Figure 1A*). The letter zone indicates the mediolateral location of greatest protrusion (A = sagittal, B = parasagittal, C = foraminal; see *Figure 1B*). In some cases, the amount of compression is nearly equal in zones A and B, so a zone classification of AB is used. Using this scheme, 7 distinct classes of CDHs were identified in the sample population (*Figures 1*,*2*).

Surgical procedure for cervical discectomy

We determined the optimal surgical course based on MRI (FFS classification), clinical experience, and full communication and consent with the patient, including the following approaches (12).

The anterior approach was performed in the supine position under general anesthesia, making a suitable incision according to the surgical segment, cutting and separating to the anterior fascia, exposing the vertebral body, occluding the intervertebral disc and the upper and lower cartilage plates, placing a fusion device, reinforcing with titanium plates, or Zero-P, determining the satisfactory internal fixation, flushing the incision, stopping bleeding thoroughly, placing a drainage tube, and suturing the incision. The posterior approach was performed in the prone position, with the surgical incision made and the endoscopic working channel established by continuous dilatation of the tube, and the operation was performed under continuous saline irrigation. The medial aspect of the upper and lower articular processes was located, and here the intervertebral foramen was entered with a grinding drill, and part of the ligamentum flavum was occluded to expose the spinal nerve roots. The nucleus pulposus was carefully explored and then dremeled away to allow adequate decompression of the compressed spinal nerve. For clinical practice procedures, all patients received postoperative physiotherapy and exercise to enhance cervical spine

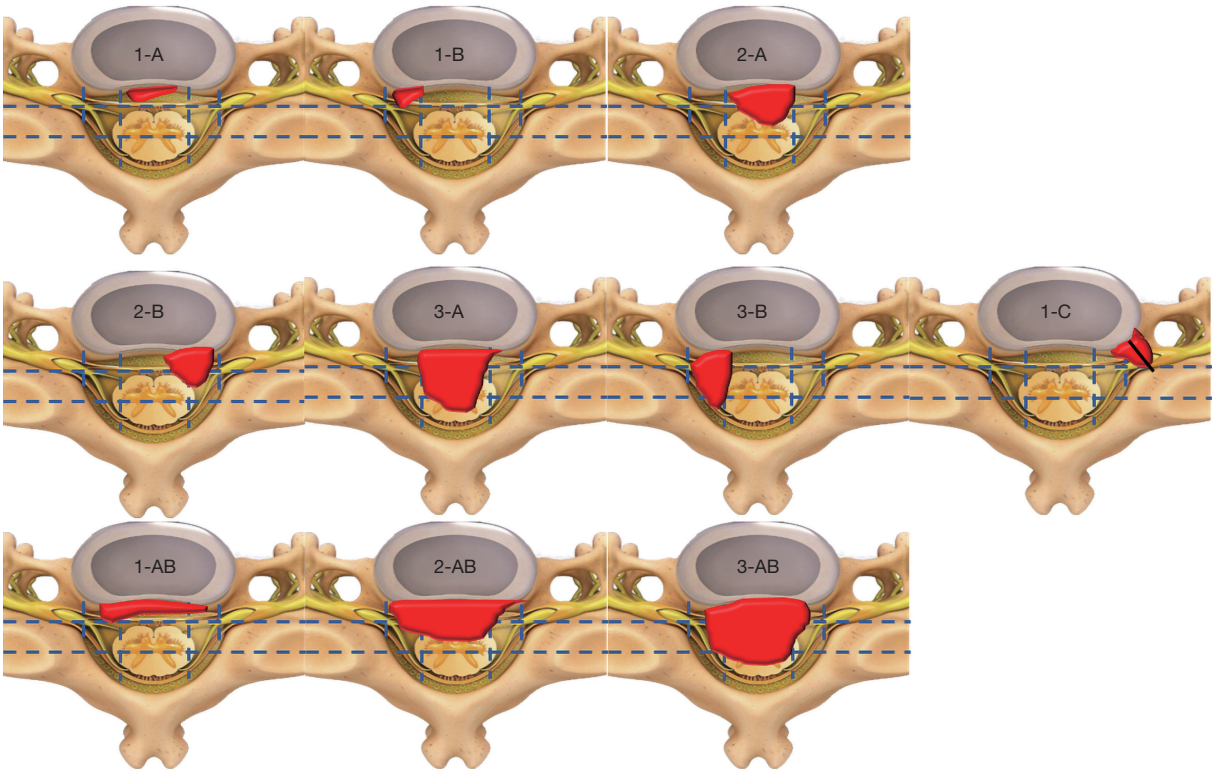

Figure 2 Combining size and location.

mobility. Some 90% of the participants were in compliance with this recommendation.

Statistical analysis

Continuous variables were recorded as mean ± standard deviation (SD) and categorical variables were expressed as proportions (%). Multigroup analysis of variance (ANOVA) least significant difference (LSD) tests were performed to compare means or data distributions for continuous variables. Categorical variables were compared using the χ^2 (chi-square) test or Fisher's exact test as appropriate. Kendall's W coefficient was used to test the consistency of the 3 doctors' diagnoses. Bonferroni test was used to compare the clinical scores among different types. All statistical tests were performed using SPSS 22.0 (IBM Corp., Armonk, NY, USA) and P values <0.05 were considered statistically significant.

Ethical statement

The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). This dual-center prospective study was approved by the Institutional Review Boards of the Changzheng and 910 Hospitals. Informed consent was provided by all individual study participants.

Results

Patient population

A total of 170 patients (98 males/72 females) with a mean age of 55.56±9.32 years and a duration of symptoms of 14.92±10.57 months were included in this study, some participants with a history of smoking, alcohol consumption, hypertension, and diabetes mellitus (*Table 1*).

The total complication rate was 9.41%, including postoperative axial pain in 7 patients, C5 nerve palsy in 4, compressive epidural hematoma in 2 which required emergency reoperation, wound infection in 1, and cerebrospinal fluid leak in 2. All of these patients were treated promptly with symptomatic rehabilitation such as anti-infection, rehydration, and pain relief, and had

Table 1 Clinical characteristics of patients

Characteristics	Series (n=170)
Age(years)	55.56±9.32
Sex (male/female)	98/72
BMI (kg/m^2)	24.97±2.56
Smoking (yes/no)	76/94
Drinking (yes/no)	58/112
Diabetes (yes/no)	31/139
Hypertension (yes/no)	63/107
Duration of symptoms (months)	14.92±10.57

Data are presented as mean ± SD or number. BMI, body mass index; SD, standard deviation.

Table 2 Total complications of the two series

Characteristics	Postoperative	After 3 months	After 12 months
Number of C5 palsies	4 (2.35)	2 (1.17)	1 (0.59)
Axial neck pain	7 (4.12)	4 (2.35)	2 (1.18)
Symptom recurrence	–	0	2 (1.17)
Reoperation rate	–	0	1 (0.59)
Cerebrospinal fluid leakage	2 (1.18)	0	0
Postoperative hematoma	2 (1.18)	0	0
Wound treatment	1 (0.59)	0	0
Total complication rate	16 (9.41)	–	–

Data are presented as n (%).

recovered by the 3-month follow-up. At the last follow-up, 2 patients had reappearance of symptoms and 1 patient had undergone revision surgery (*Table 2*).

No patients were lost to follow-up. After scoring by 3 examiners (2 examiners disagreed on the same case, which was assessed by the third examiner), 1-A, 1-B, 1-AB, and less severe 1-C patients were selectively excluded. The proportion of excluded cases was 15% (30/200). The Kendall's W coefficient of the diagnostic results was 0.888, P<0.001, with strong consistency.

Disability scores

The numbers of patients with 2-A, 3-A, 2-B, 3-B, 2-AB, 3-AB, and 1-C were 30, 20, 25, 15, 40, 25, and 15, respectively. Motor function scores were higher for 1-C, 2-A, and 2-B than for other classifications; sensory function scores were relatively lower for 3-A, 2-A, and 2-AB than those for the other grades; bladder function scores were relatively low for 2-A, 3-A, and 3-AB as compared to other categories, with a statistically significant difference, P<0.05 (*Table 3*). Preoperative scores were highest for type 1-C and lowest for type A. At the last follow-up, pain symptoms had improved significantly in all patients, and no statistical significance was observed in the difference in VAS scores. For those with 2-A and 3-A, hyperreflexia, Hoffmann's sign (+), and Babinski's sign (+) were higher in comparison. For those with 1-C, Spurling's test (+) and Eaton's test (+) were higher in comparison. For those with 2-B, 3-B, 2-AB, and 3-AB, signs and symptoms of both spinal cord and nerve root compression, presenting with Brown-Sequard syndrome were higher in comparison. These findings indicated that 3-AB was the most severe and 1-C was mainly a sensory impairment (*Tables 3*,*4* and *Figure 3*)

The VAS/JOA scores improved significantly in all patients, especially in area AB and grade 3 (*Table 4*). The rate of good/excellent outcomes at JOA scores was 94.70% (161/170) at 3 months and 92.35% (157/170) at 1 year postoperatively. All patients with preoperative neurological impairment showed neurological improvement postoperatively (*Table 5*). No significant differences in the improvement rates were observed during the short-term follow-up period, which was considered statistically insignificant in terms of clinical outcomes, with better postoperative scores (*Table 5*).

Discussion

CDH is a common source of cervical radiculopathy and myelopathy (5). It has been reported that most patients with radiculopathy have severe neck and arm pain, and sensory symptoms (e.g., burning, tingling sensations) following dermatomal distribution, and altered reflexes and motor weakness may also occur (13). MRI images demonstrate degeneration and herniation of cervical intervertebral discs, which can worsen with age. Surgical treatment should be considered if conservative treatment is ineffective, if symptoms persist, or even if the dysfunction progresses.

The deep tendon reflex is specific to each intervertebral level, but there is no neurological sign that is both highly sensitive and specific to the intervertebral level (14). Moreover, it is not uncommon for clinical radiculopathy and herniated disc levels to differ on MRI (15). CDH is classified as central, paracentral, and lateral, but cannot be quantified

Table 3 Characteristics and severity of the symptoms of patients

Variables	2-A (n=30)	3-A (n=20)	2-B (n=25)	3-B (n=15)	2-AB (n=40)	3-AB (n=25)	1-C (n=15)
Motor function	4.73±1.08	3.75±1.12	5.32±1.11	3.87±1.25	3.78±1.17	3.52±1.58	5.80±1.32
Sensation	4.23±1.10	4.75±1.02	3.24±1.20	2.67±1.35	4.15±1.25	2.60±1.08	2.67±0.90
Bladder function	1.97±0.89	1.40±0.99	2.28±0.79	1.93±1.03	2.18±0.75	1.12±0.88	2.00±0.76
Pre VAS score	1.83±1.21	1.30±1.13	3.40±1.30	4.27±1.10	3.35±1.58	4.96±1.49	6.40±0.91
FU VAS score	0.97±0.81	1.40±0.75	0.84±0.90	1.20±0.78	1.05±0.85	0.84±0.69	1.04±0.82
Hoffmann sign	21 (70.00)	15 (75.00)	13 (52.00)	10 (66.67)	21 (52.50)	18 (72.00)	–
Babinski sign	26 (86.67)	16 (80.00)	14 (56.00)	12 (80.00)	26 (65.00)	20 (80.00)	–
Eaton's test	–	–	9 (36.00)	8 (53.33)	15 (37.50)	13 (52.00)	13 (86.67)
Spurling's test	–	–	11 (44.00)	9 (60.00)	13 (32.50)	11 (44.00)	12 (80.00)
Abnormal reflection	23 (76.67)	18 (90.00)	13 (52.00)	8 (53.33)	29 (72.50)	17 (68.00)	4 (26.67)
Brown-Sequard syndrome	–	–	6 (24.00)	4 (26.67)	9 (22.50)	7 (28.00)	–

Data are presented as mean ± SD or n (%). FFS, foramen facet spinal; FU, follow-up; JOA, Japanese Orthopedic Association; Pre, preoperative; SD, standard deviation; VAS, visual analog scale.

Table 4 Pairwise comparisons of JOA and VAS scores between FFS classifications (Bonferroni)

Pairwise comparison	P value				
	Motor function	Sensation	Bladder function	Pre VAS score	FU VAS score
2-A *vs.* 3-A	1.000	1.000	1.000	1.000	1.000
2-A *vs.* 2-B	1.000	0.099	0.009	<0.001	1.000
2-A *vs.* 3-B	0.045	0.118	1.000	<0.001	1.000
2-A *vs.* 2-AB	1.000	1.000	0.363	<0.001	1.000
2-A *vs.* 3-AB	1.000	<0.001	1.000	<0.001	1.000
2-A *vs.* 1-C	0.192	0.001	0.502	<0.001	1.000
3-A *vs.* 2-B	1.000	0.014	0.003	<0.001	0.492
3-A *vs.* 3-B	1.000	0.019	1.000	<0.001	1.000
3-A *vs.* 2-AB	1.000	0.408	0.103	<0.001	1.000
3-A *vs.* 3-AB	1.000	<0.001	1.000	<0.001	0.492
3-A *vs.* 1-C	0.002	<0.001	0.162	<0.001	1.000
2-B *vs.* 3-B	0.232	1.000	0.532	0.975	1.000
2-B *vs.* 2-AB	1.000	1.000	1.000	1.000	1.000
2-B *vs.* 3-AB	1.000	1.000	0.092	0.001	1.000
2-B *vs.* 1-C	0.065	1.000	1.000	<0.001	1.000
3-B *vs.* 2-AB	0.174	1.000	1.000	0.490	1.000
3-B *vs.* 3-AB	1.000	1.000	1.000	1.000	1.000
3-B *vs.* 1-C	<0.001	1.000	1.000	<0.001	1.000
2-AB *vs.* 3-AB	1.000	0.010	1.000	<0.001	1.000
2-AB *vs.* 1-C	0.022	0.037	1.000	<0.001	1.000
3-AB *vs.* 1-C	0.003	1.000	1.000	0.022	1.000

FFS, foramen facet spinal; FU, follow-up; JOA, Japanese Orthopedic Association; Pre, preoperative; VAS, visual analog scale.

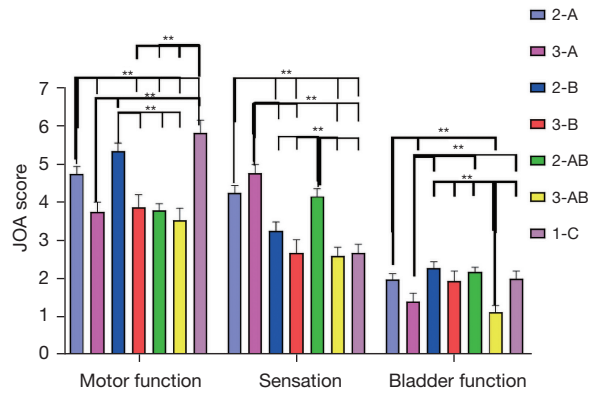

Figure 3 Comparison of JOA scores for each grading zone. **, P<0.05. JOA, Japanese Orthopedic Association.

on MRI. Beattie *et al.* reported that the presence of disc compression was associated with clinical symptoms (16). Similarly, FFS classification is highly reliable, and symptom severity varies significantly among different classifications. In patients with cervical spondylotic radiculopathy, the type and extent of disc herniation measured by MRI before surgery have been shown to be independent of symptom severity at presentation and clinical outcome 2 years after surgery (17). In this study, we were not able to show that this classification predicted outcomes, but we were able to show that patients with anterior cervical discectomy had good outcomes, such as those with severe 3-AB.

This study indicates that zone A lesions often result in spinal cord compression with weakness in both hands, often without pain. Anterior resection is feasible for zone A and AB lesions and posterior surgery for zone C lesions is feasible to rapidly relieve the neck pain and spinal cord compression and restore daily activities and functional movements of the cervical spine, with overwhelmingly excellent surgical outcomes, minimal recurrence rates, and no serious complications, so the clinical features of each grade may contribute to complete surgical removal of the mass and a better prognosis.

For many years, MRI has been the preferred technique to diagnose cervical spine disorders (6). However, a consensus has not been reached on the best quantitative MRI method for assessing CDH. The results of Karpova *et al.* suggested that measurements of spinal cord compression ratio, maximum canal injury, and maximum spinal cord compression are sufficiently reliable and correlate closely with the clinical severity of spinal cervical

Table 5 Surgical outcomes by classification scheme

Classification	Time	Excellent/ good	Fair	Poor	Total
2-A	After 3 months	29	1	0	30
	After 12 months	29	1	0	30
3-A	After 3 months	18	1	1	20
	After 12 months	17	2	1	20
2-B	After 3 months	25	0	0	25
	After 12 months	24	1	0	25
3-B	After 3 months	13	2	0	15
	After 12 months	13	1	1	15
2-AB	After 3 months	39	1	0	40
	After 12 months	38	2	0	40
3-AB	After 3 months	23	1	1	25
	After 12 months	22	2	1	25
1-C	After 3 months	14	1	0	15
	After 12 months	13	2	0	15
Total	After 3 months	161	7	2	170
	After 12 months	157	10	3	170

spondylosis (18). However, it does not significantly increase predictive performance and does not improve the discriminatory power of clinical prediction models (19). The present study also found that this grading correlated with symptom severity.

Location of the herniated disc in the responsible segment

Median (A)

The herniated disc is located directly anterior to the spinal cord, with prevailing spinal cord compression, and may present with symptoms such as weakness of the limbs, unsteadiness in walking, and a feeling of chest fasciculation. The involvement of grade 3 may be severe enough to present with quadriplegia or bladder dysfunction. Examination: There are abnormal planes of sensation in the trunk, hyperactive tendon reflexes in the lower limbs, Hoffmann's sign (+), and Babinski's sign (+). Median herniation (A) is characterized by spinal cord symptoms in which the spinal cord is compressed and deformed into a boomerang shape, resulting in central spinal cord syndrome or transverse lesion syndrome.

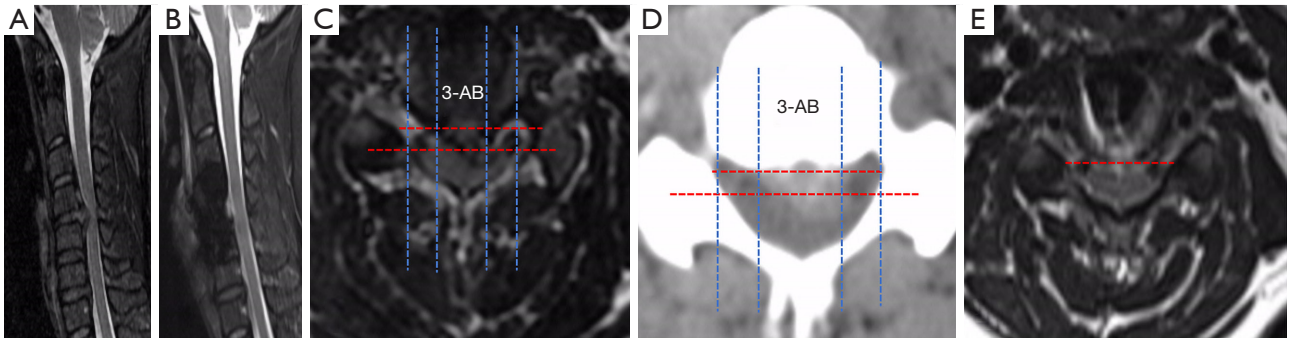

Figure 4 Representative cross-sectional imaging from an individual with a score of 3-AB and an excellent postoperative functional outcome. Female, 32 years old, complained of unsteady walking, muscle weakness, upper limb numbness, Hoffmann sign (+), Babinski sign (+). (A,C) MRI C4/5 intervertebral disc herniation (left central, 3-AB). (D) CT (3-AB). (B,E) MRI without spinal cord compression, continuous cerebrospinal fluid, thorough decompression, JOA improvement rate of 89% is excellent. The red line above means posterior line of the intervertebral foramen and the red line below means the line which connects the centers of the articular eminences on both sides. The blue line means four equal parts of spinal canal area. CT, computed tomography; MRI, magnetic resonance imaging; JOA, Japanese Orthopedic Association.

Lateral (B)

The herniated disc is located between the lateral aspect of the spinal cord and the beginning of the spinal nerve roots, and therefore has signs and symptoms of both spinal cord and nerve root compression, but patients have radicular pain symptoms that seem to mask the manifestation of spinal cord compression. In addition, patients have Brown-Sequard syndrome, which may be associated with spinal cord rotation. Lateral area (B) is characterized by unilateral compression of the spinal cord in the shape of a comma with signs and symptoms of Brown-Sequard syndrome.

Foraminal area (C)

The herniated disc is located beyond the origin of the spinal nerve roots and close to the foraminal region, with predominantly radicular symptoms, pain and numbness mainly in the upper extremities, and abnormal sensation in the upper extremities and hands according to the nerve distribution. On examination: Eaton's test (+), Spurling's test (+), the tendon reflexes innervated by the lesioned segment may be weakened, and the muscle strength may be reduced, but there is no trunk sensory abnormality. Lateral herniation pressing the nerve root in the anterolateral corner of the spinal canal towards the entrance of the intervertebral foramen can cause radiculopathy (1).

Degree of herniation

- 1: mild posterior herniation of the intervertebral disc with compression of the dural sac and little compression of the spinal cord or nerve roots, with continuous visibility of the cerebrospinal fluid band in patients and generally no signs of compression except for severe C.
- 2: the disc is obviously protruding posteriorly and may have a variety of shapes, such as tongue-shaped or umbrella-shaped, with varying degrees of spinal cord and nerve root compression.
- 3: the herniated disc may break through the annulus fibrosus and the posterior longitudinal ligament and even protrude into the epidural space, exceeding half of the sagittal diameter of the spinal canal, with irregular shape and no demarcation between it and the spinal cord. The intramedullary signal may change on T2-weighted imaging.

Studies have reported that the most important predictors of surgical outcome are baseline myelopathy severity, age, smoking status, and gait disturbance (20). The duration of symptoms, the T2-high signal, and the ratio of spinal cord compression may also be predictive of the outcome (*Figure 4*) (21).

Karpova *et al.* concluded that the degree of spinal cord compression and the pattern of signal intensity changes on T2-weighted images did not independently predict outcome, but found correlations with functional status at the time of presentation and patient age (22). Many investigators have evaluated the relationship between increased signal intensity (ISI) and outcome in cervical myelopathy. Arvin *et al.* found that MRI signal changes

predicted baseline neurological status and postoperative recovery (23). Vedantam *et al.* concluded that multi-segmental, sharp, and intense T2 ISI were associated with worse surgical outcomes (24). Thus, neurological signs and clinical scores have been correlated with ISI changes (25).

This study revealed significant differences in symptom scores and signs among patients with different FFS subtypes, reflecting the severity of herniated disc compression. The more severe the grading, the lower the clinical symptoms and scores, and the abnormal blood flow signal in the compressed segment of the spinal cord and the disturbance of cerebrospinal fluid movement may play an important role (26). FFS classification primarily reflects not only the location of intervertebral disc protrusion, but also the shape and mechanical stress of intervertebral disc protrusion indirectly. 1-C, 2-B, 3-B, and 3-AB: the stress of dagger-, sharp knife-, and mountain tip-like proportion is large. 2-AB, 3-A: the shape of the top is relatively flat, with strong stress. 2-A: relatively elliptical shape, with strong spinal cord tolerance and mild stress. Although each classification may reflect the local scissor force and stress force, their exact relationship to mechanical stress and vulnerability requires further investigation (27).

Based on the staging and experience, CDH is mostly multi-segmental degeneration, and it is important to identify the responsible segment, which can be preceded by a nerve block. We recommend anterior cervical discectomy for A and B CDH, and grade 3 must be resected posteriorly by exploring the posterior longitudinal ligament, focusing on decompression of the nerve roots and paying attention to the nerve root hooks to explore the posterior lateral herniated disc. Therefore, according to surgical experience and MRI, we recommend surgical methods for each classification, but it is not absolute. 1-C: Endoscope. Level 2 or 3: anterior cervical discectomy and fusion (ACDF) or Zero-P/artificial intervertebral disc replacement. Area B involvement: pay attention to exploring the outlet root of the nerve root and decompression of the uncinate joint. Therefore, based on FFS classification, this study not only excluded patients with mild compression (grade 1) symptoms, but also targeted intraoperative removal and decompression based on the size and location of the protrusion, improving the improvement rate and prognosis in patients who did require surgery.

Limitations

The current study has several limitations. Firstly, a single-segment CDH with more severe clinical symptoms such as muscle weakness and/or neck or arm pain was confirmed by MRI by a spine surgeon. Meanwhile, other degenerative causes (hook arthritis and small arthritis, thickening of the ligamentum flavum, cervical spondylolisthesis, etc.) or other causes of radiculopathy (malignancy, infection, fracture, dislocation, congenital anomalies) were excluded (28). Secondly, mild disc herniation was not included in the study. A strong consistency test validated the reliability of the grading system, although some participants may have been misclassified. Larger sample sizes and longer follow-up periods will be necessary in the future for comparison of improvement rates, recurrence, and long-term outcomes across different classifications.

Conclusions

The FFS classification is an objective scoring system that can be applied similarly by multiple examiners and is correlated with clinical symptoms. It is simple to learn and apply. It may improve objective criteria for surgery, optimize the discussion of discectomy, and be used as a common terminology for research. However, the significance and clinical predictive value of the FFS classification system should be further investigated in the future.

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Footnote

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://qims.amegroups.com/article/view/10.21037/qims-22-1387/coif). The authors have no conflicts of interest to declare.

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. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). This dual-center prospective study was approved by the Institutional Review Boards of the

Changzheng and 910 Hospitals. Informed consent was provided by all individual study participants.

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