Received: 22 June 2021 | Revised: 2 November 2021 | Accepted: 30 November 2021

DOI: 10.1002/jsp2.1185

SPECIAL ISSUE ARTICLE

JOR Spine OPEN ACCESS

Using the cobweb classification system as a digital location system for the neurologic compression in cervical degenerative disease

Yang Xiong[1] | Ying-Li Yang[2] | Xing Yu[1] | Feng-Xian Wang[1] | Yong-Dong Yang[1] | Ding-Yan Zhao[1] | He Zhao[1] | Chuan-Hong Li[1] | Kai-Tan Yang[1]

[1]Department of Orthopedics, Dongzhimen Hospital, Beijing University of Chinese Medicine, Beijing, China

[2]Department of Traditional Chinese Medicine, Peking Union Medical College Hospital, Beijing, China

Correspondence
Xing Yu, Department of Orthopedics, Dongzhimen Hospital, Beijing University of Chinese Medicine, No. 5 Haiyuncang Street, Dongcheng District, Beijing 100700, China.
Email: yuxing34163@163.com

Funding information
Observation on the effect of biomimetic mineralized collagen artificial bone in the treatment of spinal diseases and bone fracture, Grant/Award Number: DZM-601111

Abstract

Objective: To provide the cobweb classification system (CCS) for the precise digital location and description of the neurological compression in cervical degenerative disease (CDD), and the reliability and the clinical subgroup analysis of the system were tested and analyzed.

Methods: The CCS consisted of three parts: compression zones (**1**-**12**), degrees (**a**, **b**) and ossification (**s**, **m**, **h**). Computerized tomography (CT) and magnetic resonance imaging (MRI) images from 238 CDD patients were reviewed. All compression cases were classified by five independent reviewers with varied clinical experience in spine surgery. The reliability of the CCS was tested by calculating the kappa (κ) statistics value. Finally, 74 patients with anterior cervical surgery treatment were enrolled for the clinical subgroup analysis.

Results: For the small compression, including single and double compression zones, there was a good interobserver reliability between the reviewers (κ coefficient = .855, $P < .001$). For the large compression with three or more involved zones, there was a fair reliability between the reviewers (κ coefficient = .696, $P < .001$). The whole intraobserver reliability was good (κ coefficient = .923, $P < .001$). For clinical practice, the operative time in the large compression and the **m/h** group was significantly longer than the small compression and the **s** group, respectively ($P < .05$), and the blood loss in the **m/h** group was significantly increased as well ($P < .01$). Though the preoperative Japanese Orthopedic Association score in Group **b** was lower than Group **a** ($P < .05$), all patients had achieved significant clinical improvement at last follow-up.

Conclusions: The CCS can be used to provide detailed and objective descriptions of the location, extent, and severity of neurological compressions in CDD with satisfactory reliability. Surgeons should pay more attention to the patient with large zone, degree **b**, and ossification compression, because the operation may be more challenging.

Yang Xiong and Ying-Li Yang contributed equally to this work as co-first authors.

KEYWORDS
anterior cervical surgery, cervical degenerative disease, cobweb classification system, digital location, neurologic compression

1 | INTRODUCTION

Degeneration of the cervical spine develops in most people as we age, and the appearance of cervical disc protrusion positively correlates with the severity of the cervical degeneration.[1] Although the underlying risk factors remain to be fully characterized, the advancement of cervical degeneration can eventually lead to symptomatic spinal cord or nerve roots compression. The most common causes of neurologic compression include disc herniation, ossified and/or hypertrophic ligaments, osteoarthritis, and osteophyte formation.[2] Spinal surgical techniques have advanced rapidly over the last 50 years. However, evaluation of the location and severity of neurologic compression is still mainly relegated to an often incomplete and short non-standardized text description in clinical practice.[3,4] To maximize the benefit from the great progress in surgical techniques, it is necessary for surgeons to be able to accurately and objectively evaluate the location and severity of neurologic compression before making decisions on the specific surgical procedures. Although there are lots of quantitative grading or scoring reports on the analysis of the neurological compression in cervical degenerative diseases (CDDs), researches on digital location of the compression at the cross-section of injured level remain rare.

For the first time, we propose a novel cobweb classification system (CCS), whose reliability we have tested and analyzed, for the digital description of the location and severity of neurological compression in CDD.

2 | METHODS

2.1 | Patients

For reliable analysis, a total of 1648 computerized tomography (CT) and magnetic resonance imaging (MRI) images of 238 patients with CDD, including 412 degenerated segments, were reviewed from January 2016 to December 2019. And 74 patients were enrolled for the clinical subgroup analysis. All patients met the following conditions: symptomatic CDD was diagnosed based on clinical and radiological corroborations and anterior cervical discectomy and fusion (ACDF) and/or cervical disc arthroplasty (CDA) was performed after failed conservative treatment. Patients with a history of cervical trauma or cervical spinal surgery were excluded.

2.2 | The cobweb classification system

We developed the CCS based on the following three criteria: compression zones (**1**-**12**), degrees of compression (**a**, **b**), and levels of ossification (**s**, **m**, **h**) (Figure 1). To define the compression zone, a *central circle* was drawn across the vertebral body in the cross-section. The central point of the vertebral body (point **O**) was placed as the center of the *central circle*. The radius of the circle was the distance from point **O** to the tip of the lateral uncinate process. The *central circle* was divided into 12 equally spaced zones numbered as zones **1** to **12**, in a clockwise direction. The lines at the boundaries of zones **3** to **9** were extended. The extended boundary lines of zones **4**, **5**, **6**, **7**, and **8** intersected the posterior vertebral arch at points B, D, C, and A, respectively. Points A and B were close to the medial edge of bilateral facet joints, and points C and D were close to the root of the spinous process. Thus, zones **4** and **8** corresponded to the bilateral intervertebral foramen (yellow area **L** and green area **R** in Figure 1, respectively), and zones **5** through **7** corresponded to the spinal canal area (blue area **M** in Figure 1).

In order to distinguish different degrees of compression, areas **L**, **R**, and **M** were divided into two parts (**a** and **b**). A compression of degree **a** represents any compression localized to part **a**, that is, <1/2 of the sagittal diameter of the spinal canal while a compression of degree **b** represents any compression extended into part **b**, that is, ≥1/2 of the sagittal diameter of the spinal canal. Zones **3** and **9** were also divided into two parts (**a** and **b**) according to vertical lines extended from points A and B, respectively, as shown in Figure 1. To distinguish ossification, all the herniated tissues were classified as soft (**s**), ossified/hard (**h**), or mixed (**m**) according to the corresponding CT features. All the compressions were classified as small or large according to the number of compression zones involved. Using the proposed system above, all aspects of common spinal cord or nerve roots compressions can be accounted for and accurately described.

2.3 | Clinical application of the CCS

The CCS, as a supplementary for preoperative surgical decision-making, can be easily applied clinically. The compression zones (**1**-**12**) in the CCS were designed in a clockwise direction. For surgeons, the digital location of any degenerative protrusion through CCS is as convenient as determining the time through a clock. Three cases were given to show the digital location and description of the neurological compression through the CCS:

Case 1 (Figure 2): A 58-year-old male patient with myelopathy symptoms related to C5-6 level. MRI and CT scan showed a small compression with a single compression zone (**6as**) in CCS. With 2-year follow-up after the CDA surgery, a satisfactory clinical outcome was achieved.

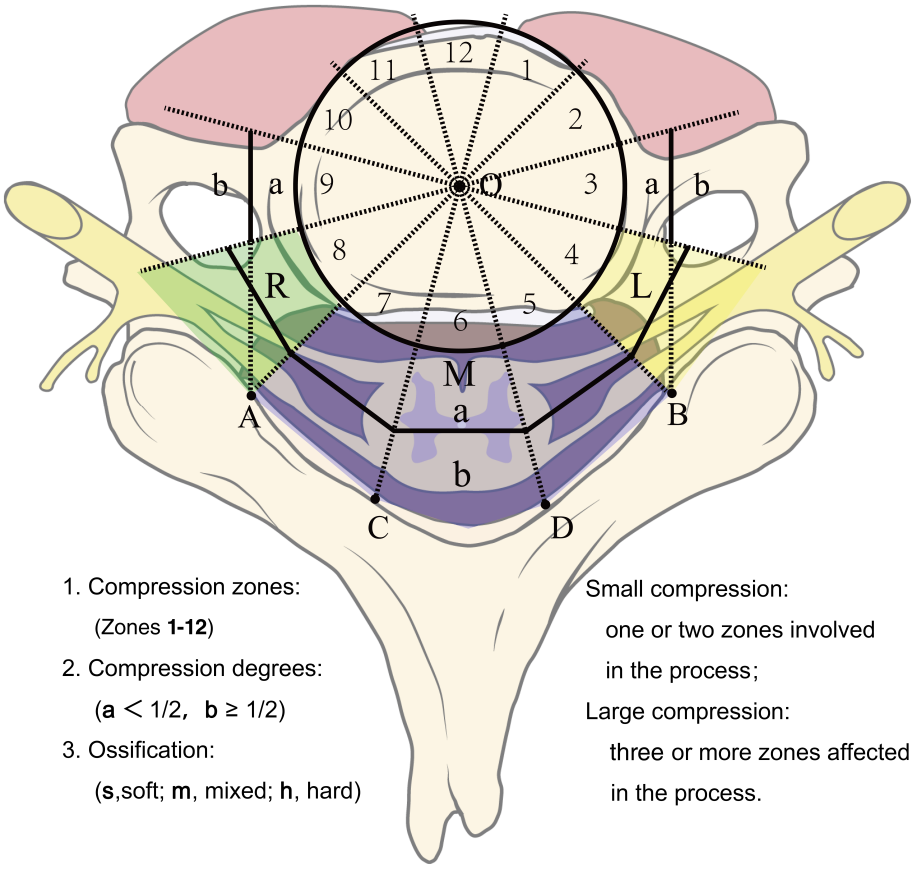

FIGURE 1 Schematic representations of the cobweb classification system (CCS)

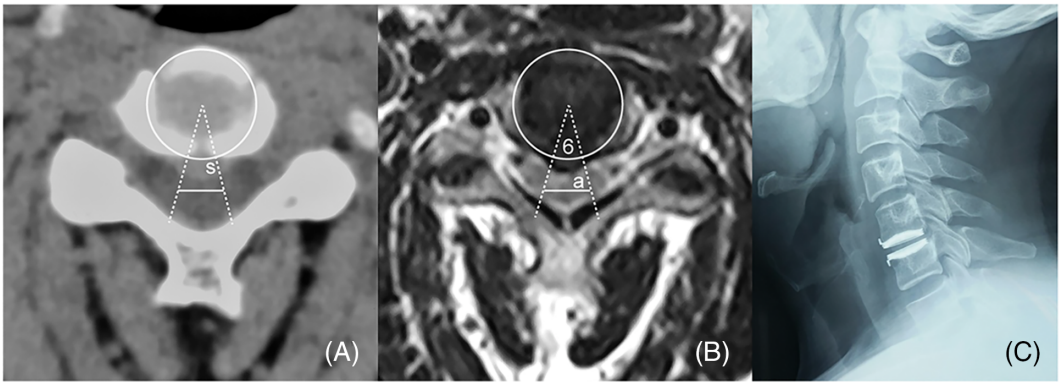

FIGURE 2 A small compression with a single compression zone (**6as** in CCS). (A) CT scan in cross-section. (B) Corresponding MRI section. (C) Lateral radiograph, 2-year postoperation. CCS, cobweb classification system; CT, computerized tomography; MRI, magnetic resonance imaging

Case 2 (Figure 3): A 50-year-old female patient with cervical radiculopathy symptoms related to C5-6 level. MRI and CT scans showed a small compression with two compression zones (**78bm**) in CCS. With 1-year follow-up after the ACDF surgery, a satisfactory clinical outcome was achieved.

Case 3 (Figure 4): A 69-year-old female patient with cervical myeloradiculopathy symptoms related to C5-6 level. MRI and CT scans showed a large compression with four compression zones (**5678bm**) in CCS. At 1-year follow-up after the ACDF surgery, the patient's symptoms had subsided almost totally.

2.4 | Reviewers' criteria

Five independent individuals with different clinical experiences, including two original developers of the CCS and three randomly selected spine surgeons, were chosen as reviewers. Spinal

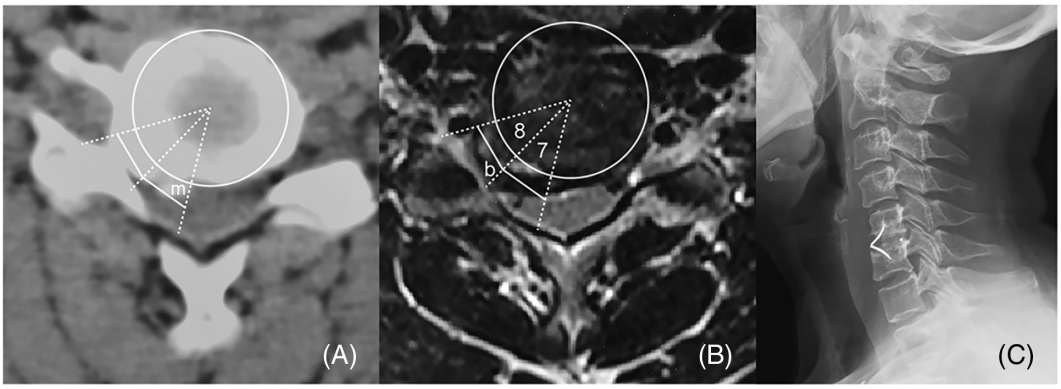

FIGURE 3 A small compression with two compression zones (**78bm** in CCS). (A) CT scan in cross-section. (B) Corresponding MRI section. (C) Lateral radiograph, 1 year postoperation. CCS, cobweb classification system; CT, computerized tomography; MRI, magnetic resonance imaging

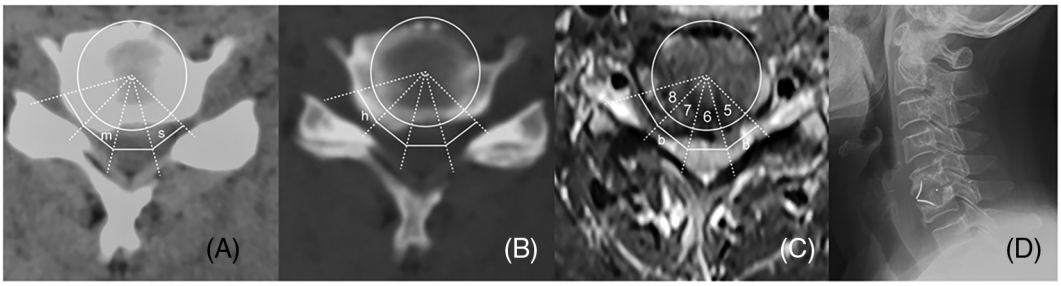

FIGURE 4 A large compression with four compression zones (**5678bm** in CCS). (A) Soft tissue window of the CT scan. (B) Bone window of the CT scan. (C) MRI image of the corresponding section. (D) Lateral radiograph, 1 year postoperation. CCS, cobweb classification system; CT, computerized tomography; MRI, magnetic resonance imaging

compressions from 412 cervical degenerative segments were classified and recorded by all reviewers independently based on 1648 corresponding CT and MRI images. A month later, all reviewers were asked to reevaluate the same images.

2.5 | Clinical subgroup analysis

Based on the CCS, 74 enrolled patients were divided into 3 pairs of comparative subgroups. Patients with any segment of large compression or degree **b** compression or ossification were divided into the large compression group (Group LC) or Group **b** or Group **m/h**, respectively. The Japanese Orthopedic Association (JOA) score, the Neck Dysfunction Index (NDI) score, Visual Analogue Scale (VAS) of neck pain and arm pain were used to evaluate the clinical outcomes of the patients.

2.6 | Statistical analysis for reliability assessment

The classification results from five independent reviewers were compared to evaluate the reliability of the CCS. Both the interobserver and intraobserver reliabilities were estimated by calculating the kappa (κ) coefficient values of simple and weighted components at 95% confidence intervals as established with SAS software (SAS Institute, Cary, North Carolina). The κ coefficients ranged from +1 to 0 to −1, which means perfect agreement to chance agreement and to less agreement than expected by chance. Based on the publication by Svanholm et al, the κ values >.75 represent good or excellent reliability; and κ values between .5 and .75 indicate fair reliability; and κ values <.5 reflect poor reliability.[5] For the subgroup analysis, the results were expressed as mean ± SD. The independent-samples *t*-test was used to compare the data between subgroups. The Wilcoxon signed rank test or paired-samples *t*-tests were used to evaluate the data between preoperative and postoperative parameters. A *P*-value <.05 was considered statistically significant.

3 | RESULTS

3.1 | Reliability assessment outcomes

A good interobserver reliability between the reviewers was determined for analysis of the small compression cases (κ coefficient = .855, $P < .001$). For the large compression with three or more involved zones, the interobserver reliability was fair (κ coefficient = .696, $P < .001$). The intraobserver reliability for both small and large compressions was good (κ coefficient = .923, $P < .001$), which was based

TABLE 1 Patients' demographic and surgical data

Item	Group SC	Group LC	*P*	Group a	Group b	*P*	Group s	Group m/h	*P*
No. of patients	51	23	—	62	12	—	56	18	—
Myelopathy	20	9	—	22	7	—	19	10	—
Radiculopathy	28	9	—	34	3	—	31	6	—
Myeloradiculopathy	3	5	—	6	2	—	6	2	—
Age, y	53.29 ± 7.40	54.73 ± 8.09	.628	54.05 ± 7.07	54.62 ± 6.13	.810	54.13 ± 7.73	55.26 ± 8.35	.684
Male (ratio)	27 (52.94%)	10 (43.48%)	.451	30 (48.39%)	7 (58.33%)	.528	30 (53.57%)	7 (38.89%)	.278
Operative time, min	124.49 ± 17.23	136.22 ± 21.16	.038	125.82 ± 16.48	133.49 ± 22.74	.137	125.46 ± 19.53	135.78 ± 21.75	.016
Blood loss, mL	28.76 ± 12.47	35.69 ± 15.80	.209	27.82 ± 13.88	29.56 ± 19.30	.705	27.84 ± 14.52	36.56 ± 18.63	.007
Follow-up, mo	27.34 ± 13.61	26.68 ± 14.34	.653	26.93 ± 14.76	27.05 ± 12.14	.636	27.02 ± 13.51	27.95 ± 14.63	.501

Note: A *P*-value <.05 was considered statistically significant.
Abbreviations: Group **a**, compression degree **a**; Group **b**, compression degree **b**; Group **m/h**, mixed or hard compression; Group **s**, soft compression; LC, large compression; SC, small compression.

TABLE 2 A summary of clinical outcomes

Item	Group SC	Group LC	*P*	Group a	Group b	*P*	Group s	Group m/h	*P*
JOA pre-op	14.53 ± 0.79	13.67 ± 1.05	.229	14.77 ± 0.61	12.54 ± 0.50	.042	14.48 ± 1.17	13.95 ± 0.85	.368
JOA last	16.22 ± 0.52*	16.12 ± 0.64*	.857	16.41 ± 0.73*	16.07 ± 0.99*	.546	16.26 ± 0.64*	16.13 ± 0.86*	.745
NDI pre-op	30.74 ± 16.48	31.03 ± 14.16	.529	29.95 ± 17.43	30.82 ± 19.26	.348	30.63 ± 15.33	31.96 ± 19.60	.274
NDI last	6.27 ± 2.81*	7.40 ± 4.55*	.668	6.67 ± 3.14*	7.12 ± 4.36*	.711	6.74 ± 3.15*	6.93 ± 4.46*	.882
VAS of neck pain pre-op	4.25 ± 1.08	4.53 ± 1.17	.342	4.29 ± 1.97	4.33 ± 1.03	.519	4.45 ± 1.53	4.62 ± 1.77	.464
VAS of neck pain last	0.77 ± 0.61*	0.83 ± 0.82*	.501	0.71 ± 0.50*	0.79 ± 0.44*	.428	0.74 ± 0.46*	0.78 ± 0.63*	.267
VAS of arm pain pre-op	3.89 ± 1.45	4.04 ± 1.03	.308	3.92 ± 1.36	4.15 ± 1.47	.295	3.75 ± 1.31	3.97 ± 1.84	.304
VAS of arm pain last	0.52 ± 0.74*	0.48 ± 0.55*	.266	0.51 ± 0.82*	0.50 ± 1.03*	.433	0.53 ± 0.69*	0.52 ± 0.43*	.467

Note: A *P*-value <.05 was considered statistically significant.
Abbreviations: Group **a**, compression degree **a**; Group **b**, compression degree **b**; Group **m/h**, mixed or hard compression; Group **s**, soft compression; JOA, Japanese Orthopedic Association; last, last follow-up; LC, large compression; NDI, Neck Dysfunction Index; pre-op, preoperation; SC, small compression; VAS, Visual Analogue Scale.
*$P < .05$ compared with per-operation.

on readings at two-time intervals and at a minimum of 1 month apart. This indicated that the CCS had both good interobserver and intraobserver reliability, and it was reliable to be used as a supplementary quantitative tool for the surgical decision-making.

3.2 | Demographic outcomes

Patients in group small compression (SC), Group **a**, and Group **s** were more than Group LC, Group **b**, and Group **m/h**, respectively. But no significant difference was detected in terms of the mean age, male ratio, and mean follow-up ($P > .05$). For surgical data, the operative time in the LC and the **m/h** group was significantly longer than the SC and the **s** group, respectively ($P < .05$), and the blood loss in the **m/h** group was significantly increased as well ($P < .01$). The result informed that patients with large or ossificated compression may carry a higher surgical risk.[6-8] And the CCS may improve the prediction of a patient with more severe compression. A summary of demographic and surgical data were shown in Table 1.

3.3 | Clinical outcomes

The inter-subgroup comparison showed that the preoperative JOA score in Group **b** was statistically lower than that in Group **a** ($P < .05$). For intra-subgroup comparison, the postoperative mean JOA, NDI, and VAS scores in all subgroups significantly improved when compared with preoperative values ($P < .05$). But there was no significant difference between every two subgroups at the last follow-up ($P > .05$). Clinical outcomes can be influenced by multiple factors, including the degree of compression, the surgical techniques and implants, the patient's sociodemographic and psychological factors.[9-12] However, the indispensable sine qua non for achieving satisfactory clinical outcomes remains early diagnosis and complete decompression. A summary of clinical outcomes were shown in Table 2.

4 | DISCUSSION

Since the first report of ACDF surgery in the 1950s, the surgical treatment of CDD has progressed rapidly and advanced greatly. Especially in the last two decades, the emergence of various new technologies and devices has led to rapid development of the surgical treatment of CDD. These changes were accompanied by both opportunities and challenges. The degeneration of the cervical intervertebral disc was first graded by the X-ray method[13] and a variety of novel classification methods have been developed for clinical application in recent years,[14-16] which include several etiological factors of CDD, such as ossification of the posterior longitudinal ligament (OPLL), ossification of the ligamentum flavum (OLF), spinal stenosis, hyperplasia of the uncinate process, and postoperative heterotopic ossification (HO).[17-24] Some studies classified the signal intensity of the cervical spinal cord through MRI images. The results showed that changes in the intensity may correlate with clinical symptoms in cervical spondylotic myelopathy.[25] Patients with low signal intensity might experience good surgical outcome and greater recuperative potential.[26] But increased signal intensity with wide range might relate to deteriorate preoperative neurological function and poorer surgical outcomes.[27] Other studies had graded or scored the degree of cervical spinal degeneration or nerve compression either preoperation or postoperation.[28-31] These methods were helpful to the quantitative analysis of local lesions. However, most of the techniques had only limited clinical application, because of the heterogeneity characterized by different definitions. In addition, they missed the digital location function at the cross-section level. It is important to accurately locate the neurological compression to effectively achieve complete decompression and satisfactory clinical results. So far, the most commonly used location methods in clinical practice are still based on text descriptions that often lack sufficient details and accuracy.[1,3] Mysliwiec et al used the MSU system to generate digital partition and location of lumbar disc herniation.[32] However, this method is only applicable to the localized protrusion and cannot be applied to the large or wide-ranged protrusion. Furthermore, the method neither accurately determined the left or right position nor establishes if there was accompanying ossification, which may have a significant impact on the surgical decision-making.

Compared with previous studies, the CCS system that we propose has the following advantages: (a) the neurological compression will be digitally located and graded objectively; (b) the number of involved compression zones immediately reflects the shape and extent of the compression as small/localized or large/wide-ranged and; (c) the ossification can be easily diagnosed by preoperative CT scans. Thus, the CCS, which involves three parameters of the spine, could have promising prospects for clinical applications.

Based on different anatomical structures, each compression zone of CCS may relate to different clinical application potential. Zone **12** contains the anterior midline of the cervical spine, which could be used to locate the midline in the anterior cervical surgery. Large osteophytes might be seen in this region in patients with diffuse idiopathic skeletal hyperostosis (DISH) disease or HO.[33] Zone **1** is symmetrical to zone **11**, and the medial border of the longus colli attaches to this area. In order to fully expose the intervertebral space during the ACDF surgery, the longus colli should be distracted to the ending point of zone **2** while the contralateral tissue should reach the starting point of zone **10**. Thus, the distance from these two points to the median line could be measured preoperatively as a reference for the intraoperative distraction of the longus colli. Zones **3** and **9** are adjacent to vertebral arteries, and decompression in this region should be extremely careful. In particular, the risk of vertebral artery injury would be greatly increased if the operation range exceeded the dividing line of **a** and **b** corresponding to zones **3** and **9** during surgeries with total resection of the uncinate process. Preoperative evaluation is the most effective way to avoid intraoperative vertebral artery injury.[34] Therefore, the horizontal distance from this dividing line to the midline could be measured preoperative to determine the safe

range of uncinate process resection. Zones **4** and **8** corresponded to the bilateral intervertebral foramen (areas **L** and **R**). Clinically, the nerve root symptoms would be more common when the hyperplasia enters region **b**. This is a key point to the efficient decompression of intervertebral foramen, as it only requires the removal of the uncinate process in zones **4** and **8**.[35] Zones **5**, **6**, and **7** were the most common sites of cervical disc herniation in clinical practice. However, different clinical symptoms could be induced between zone **6** and the adjacent zones: compression in zone **6** might lead to spinal cord symptoms, while zones **5** and **7** might cause nerve root symptoms. And the dividing line between **a** and **b** corresponding to zone **6** is close to the K line of the vertebral canal in sagittal plane.[36] However, some large compression involving zone **6** can result in varying symptoms, which included nerve root symptoms, spinal cord symptoms, or mixed symptoms. Thus, both radiological and clinical findings should be evaluated to locate the responsible compression site precisely. It should be noted that protrusions in region **a** may not necessarily cause clinical symptoms, but we found that, the closer the protrusion is to region **b**, the more severe the compression is. Also, the more compression zones involved, the more extensive the neurological compression is. Finally, ossification of the protrusion might also affect the surgical decision-making and will bring additional challenges to the decompression procedure. Using CCS, a detailed and accurate evaluation of a given case of compression will provide valuable guidance for surgical decompression of the cervical spine.

In this study, we observed a good interobserver reliability for the small compression cases and a fair interobserver reliability for the large compression cases. Several factors may account for these findings. First, there are inevitable systematic errors during the reading process. Second, the large compression involves more compression zones, which also increased the bias in comparison to the small compression cases. Although the evaluation by multiple (five) reviewers with varying surgical experience could also increase the bias, we noticed only slight differences in the judgment of the potential decompression site, and the intraobserver reliability for both small and large compressions was good. The results in this study demonstrate that the CCS is suitable for clinical applications with satisfactory reliability.

For clinical practice, the result of subgroup analysis showed that patients with large or ossificated compression may have a longer operative time and more blood loss. And patients with degree **b** compression may have a severe neurological deficit. These results informed that surgeons should pay more attention to the patients with large or degree **b** or ossificated compression because the decompression operation may be more challenging. And sufficient decompression is still the primary goal of the surgery for CDD patients.

In our initial clinical experience, the CCS can make the surgical planning more accurate, and also assist surgeons to implement the surgical planning more precisely. CCS has the potential to facilitate the collection and categorization of detailed data on neurological compression and provide guidance on optimal treatment plans. For further potential clinical application assessment, additional studies are needed with the focus on the minimal invasive surgeries, the robot-assisted surgeries, and the evaluation of spinal tumors and deformities.

5 | LIMITATIONS

The current study presents some limitations. First, only patients with anterior cervical decompression were enrolled for the subgroup analysis. This results in non-comprehensiveness of the subgroup analysis of the CDD. An additional clinical analysis for the patients with OPLL or OLF requires posterior decompression would have been useful in order to fully assess the validity of the CCS. In addition, patients from single hospital may lead to statistical bias in the final data. A larger cohort study with multiple research centers is needed to get more reliable results. Second, the mean follow-up is relatively short, mid- to long-term follow-up is required to determine whether there is a significant relationship between the subgroups in the CCS and the clinical outcomes. Finally, the correlation between the CCS and the clinical symptoms of CDD has not been established, a correlation-regression study is needed to address the problem.

In conclusion, the CCS can be used to provide detailed and objective descriptions of the location, extent, and severity of neurological compressions in CDD with satisfactory reliability. Adoption of CCS will be beneficial for the assessment of neurological compression and assisting the treatment decision-making.

ACKNOWLEDGMENT

This study was supported by the program of Observation on the effect of biomimetic mineralized collagen artificial bone in the treatment of spinal diseases and bone fracture (DZM-601111).

CONFLICT OF INTEREST

The authors declare no potential conflict of interest.

AUTHOR CONTRIBUTIONS

Yang Xiong and Xing Yu designed the study. Yang Xiong and Ying-Li Yang analyzed the data and contributed to writing the manuscript. All authors revised the manuscript critically. All authors have read and approved the final submitted manuscript.

ORCID

Yang Xiong https://orcid.org/0000-0001-9977-5866
Ying-Li Yang https://orcid.org/0000-0002-8436-6856
Xing Yu https://orcid.org/0000-0002-7917-2205
Feng-Xian Wang https://orcid.org/0000-0003-3646-4862
Yong-Dong Yang https://orcid.org/0000-0002-9484-3513
Ding-Yan Zhao https://orcid.org/0000-0002-8204-989X
He Zhao https://orcid.org/0000-0003-3833-4818
Chuan-Hong Li https://orcid.org/0000-0001-6940-3797
Kai-Tan Yang https://orcid.org/0000-0001-8484-3272

REFERENCES

1. Nakashima H, Yukawa Y, Suda K, Yamagata M, Ueta T, Kato F. Cervical disc protrusion correlates with the severity of cervical disc degeneration: a cross-sectional study of 1211 relatively healthy volunteers. *Spine (Phila Pa 1976)*. 2015;*40*(13):E774-E779. doi:10.1097/brs.0000000000000953
2. Ehara S, Shimamura T, Nakamura R, Yamazaki K. Paravertebral ligamentous ossification: DISH, OPLL and OLF. *Eur J Radiol*. 1998;*27*(3):196-205. doi:10.1016/s0720-048x(97)00164-2
3. Fardon DF, Milette PC. Nomenclature and classification of lumbar disc pathology. Recommendations of the combined task forces of the North American Spine Society, American Society of Spine Radiology, and American Society of Neuroradiology. *Spine (Phila Pa 1976)*. 2001;*26*(5):E93-E113. doi:10.1097/00007632-200103010-00006
4. Yamazaki S, Kokubun S, Ishii Y, Tanaka Y. Courses of cervical disc herniation causing myelopathy or radiculopathy: an analysis based on computed tomographic discograms. *Spine*. 2003;*28*(11):1171-1175. doi:10.1097/01.BRS.0000067262.69584.0A
5. Svanholm H, Starklint H, Gundersen HJ, Fabricius J, Barlebo H, Olsen S. Reproducibility of histomorphologic diagnoses with special reference to the kappa statistic. *APMIS*. 1989;*97*(8):689-698. doi:10.1111/j.1699-0463.1989.tb00464.x
6. Zhang L, Cao H, Chen Y, Jiao G. Risk factors for venous thromboembolism following spinal surgery: a meta-analysis. *Medicine*. 2020;*99*(29):e20954. doi:10.1097/MD.0000000000020954
7. Xing D, Ma J, Ma X, et al. A methodological, systematic review of evidence-based independent risk factors for surgical site infections after spinal surgery. *Eur Spine J*. 2013;*22*(3):605-615. doi:10.1007/s00586-012-2514-6
8. Zhu C, Wang B, Yin J, et al. Risk factors for postoperative delirium after spinal surgery: a systematic review and meta-analysis. *Aging Clin Exp Res*. 2020;*32*(8):1417-1434. doi:10.1007/s40520-019-01319-y
9. Skolasky RL, Albert TJ, Vaccaro AR, Riley LH. Patient satisfaction in the cervical spine research society outcomes study: relationship to improved clinical outcome. *Spine J*. 2009;*9*(3):232-239. doi:10.1016/j.spinee.2008.03.001
10. Adogwa O, Elsamadicy AA, Cheng J, Bagley C. Pretreatment of anxiety before cervical spine surgery improves clinical outcomes: a prospective, single-institution experience. *World Neurosurg*. 2016;*88*:625-630. doi:10.1016/j.wneu.2015.11.014
11. Wichmann TO, Rasmussen MM, Einarsson HB. Predictors of patient satisfaction following anterior cervical discectomy and fusion for cervical radiculopathy. *Clin Neurol Neurosurg*. 2021;*205*:106648. doi:10.1016/j.clineuro.2021.106648
12. Lehrich BM, Goshtasbi K, Brown NJ, et al. Predictors of patient satisfaction in spine surgery: a systematic review. *World Neurosurg*. 2021;*146*:e1160-e1170. doi:10.1016/j.wneu.2020.11.125
13. The atlas of standard radiographs of arthritis. *Rheumatology (Oxford)*. 2005;*44*(suppl 4):v46-v72. doi:10.1093/rheumatology/44.suppl_4.iv43
14. Lee S, Kim S, Lee S, et al. Percutaneous endoscopic lumbar discectomy for migrated disc herniation: classification of disc migration and surgical approaches. *Eur Spine J*. 2007;*16*(3):431-437. doi:10.1007/s00586-006-0219-4
15. Halldin K, Lind B, Rönnberg K, et al. Three-dimensional radiological classification of lumbar disc herniation in relation to surgical outcome. *Int Orthop*. 2009;*33*(3):725-730. doi:10.1007/s00264-008-0519-x
16. Jensen TS, Albert HB, Soerensen JS, Manniche C, Leboeuf-Yde C. Natural course of disc morphology in patients with sciatica: an MRI study using a standardized qualitative classification system. *Spine (Phila Pa 1976)*. 2006;*31*(14):1605-1612; discussion 1613. doi:10.1097/01.brs.0000221992.77779.37
17. Tsuyama N. Ossification of the posterior longitudinal ligament of the spine. *Clin Orthop Relat Res*. 1984;*184*:71-84. doi:10.1097/00003086-198404000-00010
18. Harsh GT, Sypert GW, Weinstein PR, Ross DA, Wilson CB. Cervical spine stenosis secondary to ossification of the posterior longitudinal ligament. *J Neurosurg*. 1987;*67*(3):349-357. doi:10.3171/jns.1987.67.3.0349
19. Morishita Y, Naito M, Hymanson H, Miyazaki M, Wu G, Wang JC. The relationship between the cervical spinal canal diameter and the pathological changes in the cervical spine. *Eur Spine J*. 2009;*18*(6):877-883. doi:10.1007/s00586-009-0968-y
20. Kang Y, Lee JW, Koh YH, et al. New MRI grading system for the cervical canal stenosis. *AJR Am J Roentgenol*. 2011;*197*(1):W134-W140. doi:10.2214/AJR.10.5560
21. Tubbs RS, Rompala OJ, Verma K, et al. Analysis of the uncinate processes of the cervical spine: an anatomical study. *J Neurosurg Spine*. 2012;*16*(4):402-407. doi:10.3171/2011.12.SPINE11541
22. Tian W, Fan MX, Liu YJ, et al. An analysis of paravertebral ossification in cervical artificial disc replacement: a novel classification based on computed tomography. *Orthop Surg*. 2016;*8*(4):440-446. doi:10.1111/os.12286
23. Aizawa T, Sato T, Sasaki H, Kusakabe T, Morozumi N, Kokubun S. Thoracic myelopathy caused by ossification of the ligamentum flavum: clinical features and surgical results in the Japanese population. *J Neurosurg Spine*. 2006;*5*(6):514-519. doi:10.3171/spi.2006.5.6.514
24. Feng F, Sun C, Chen Z. Progress on clinical characteristics and identification of location of thoracic ossification of the ligamentum flavum. *Orthop Surg*. 2015;*7*(2):87-96. doi:10.1111/os.12165
25. Smith ZA, Weber KA, Paliwal M, et al. Magnetic resonance imaging atlas-based volumetric mapping of the cervical cord gray matter in cervical canal stenosis. *World Neurosurg*. 2020;*134*:e497-e504. doi:10.1016/j.wneu.2019.10.109
26. Wang LF, Zhang YZ, Shen Y, et al. Using the T2-weighted magnetic resonance imaging signal intensity ratio and clinical manifestations to assess the prognosis of patients with cervical ossification of the posterior longitudinal ligament. *J Neurosurg Spine*. 2010;*13*(3):319-323. doi:10.3171/2010.3.SPINE09887
27. Yin L, Zhang J, Wu Y, Li J, Yang Q. Increased signal intensity of spinal cord on T2W magnetic resonance imaging for cervical spondylotic myelopathy patients: risk factors and prognosis (a STROBE-compliant article). *Medicine*. 2020;*99*(49):e23098. doi:10.1097/MD.0000000000023098
28. Nouri A, Martin AR, Mikulis D, Fehlings MG. Magnetic resonance imaging assessment of degenerative cervical myelopathy: a review of structural changes and measurement techniques. *Neurosurg Focus*. 2016;*40*(6):E5. doi:10.3171/2016.3.FOCUS1667
29. He Z, Wang N, Kang L, Cui J, Wan Y. Analysis of pathological parameters of cervical spondylotic myelopathy using magnetic resonance imaging. *Clin Neurol Neurosurg*. 2020;*189*:105631. doi:10.1016/j.clineuro.2019.105631
30. Engel G, Bender YY, Adams LC, et al. Evaluation of osseous cervical foraminal stenosis in spinal radiculopathy using susceptibility-weighted magnetic resonance imaging. *Eur Radiol*. 2019;*29*(4):1855-1862. doi:10.1007/s00330-018-5769-4
31. Leonova O, Baykov E, Sanginov A, Krutko A. Cervical disc degeneration and vertebral endplate defects after the fused operation. *Spine (Phila Pa 1976)*. 2021;*46*(18):1234-1240. doi:10.1097/BRS.0000000000004007
32. Mysliwiec LW, Cholewicki J, Winkelpleck MD, Eis GP. MSU classification for herniated lumbar discs on MRI: toward developing objective criteria for surgical selection. *Eur Spine J*. 2010;*19*(7):1087-1093. doi:10.1007/s00586-009-1274-4
33. Resnick D, Niwayama G. Radiographic and pathologic features of spinal involvement in diffuse idiopathic skeletal hyperostosis (DISH). *Radiology*. 1976;*119*(3):559-568. doi:10.1148/119.3.559
34. Neo M, Fujibayashi S, Miyata M, Takemoto M, Nakamura T. Vertebral artery injury during cervical spine surgery: a survey of more than

5600 operations. *Spine (Phila Pa 1976)*. 2008;*33*(7):779-785. doi: 10.1097/BRS.0b013e31816957a7

35. Yilmazlar S, Kocaeli H, Uz A, Tekdemir I. Clinical importance of ligamentous and osseous structures in the cervical uncovertebral foraminal region. *Clin Anat*. 2003;*16*(5):404-410. doi:10.1002/ca.10158
36. Fujiyoshi T, Yamazaki M, Kawabe J, et al. A new concept for making decisions regarding the surgical approach for cervical ossification of the posterior longitudinal ligament: the K-line. *Spine (Phila Pa 1976)*. 2008;*33*(26):E990-E993. doi:10.1097/BRS.0b013e318188b300

How to cite this article: Xiong, Y., Yang, Y.-L., Yu, X., Wang, F.-X., Yang, Y.-D., Zhao, D.-Y., Zhao, H., Li, C.-H., & Yang, K.-T. (2021). Using the cobweb classification system as a digital location system for the neurologic compression in cervical degenerative disease. *JOR Spine*, *4*(4), e1185. https://doi.org/10.1002/jsp2.1185