A Bibliometric Analysis and Visualization of Current Research Trends in the Treatment of Cervical Spondylotic Myelopathy

Mengchen Yin, MD[1],[*] ⓘ, Chongqing Xu, MD[1],[*], Junming Ma, MD[1], Jie Ye, MD[1], and Wen Mo, MD[1]

Abstract

Study Design: Bibliometric analysis.

Objective: Cervical spondylotic myelopathy (CSM) has become the most common cause of spinal cord dysfunction. Many topics of CSM still remain controversial. This study aimed to illustrate the overall knowledge structure and development trends of CSM.

Methods: Research data sets were acquired from the Web of Science database and the time span was defined as "2000 to 2019." VOS viewer and Citespace software was used to analyze the data and generate visualization knowledge maps. Annual trends of publications, distribution, H-index status, co-authorship status, and research hotspots were analyzed.

Results: A total of 2367 publications met the requirement. The largest number of articles was from the United States, followed by Japan, China, Canada, and India. The highest H-index was found for articles from the United States. The highest number of articles was published in *Spine*. The cooperation between the countries, institutes, and authors were relatively weak. Cervical sagittal alignment, predictive factor, diffusion tensor imaging, and the natural history of CSM may become a frontier in this research field.

Conclusion: The number of publications showed an upward trend with a stable rise. Most of the publications are limited to a few countries and institutions with relatively weak interaction. The United States, Canada, Japan, China, and India have made significant contributions to the field of CSM. The United States is the country with the highest productivity, not only in quality but also in quantity. Cervical sagittal alignment, predictive factor, diffusion tensor imaging, and the natural history of CSM are the research hotspots in the recent years.

Keywords

cervical spondylotic myelopathy, bibliometric analysis, visualization, research trends

Introduction

Degenerative cervical spondylotic myelopathy (CSM) has become the most common cause of spinal cord dysfunction.[1-3] With the continued aging of the global population, CSM has become an important public health priority. CSM is caused by dynamic repeated compression of the spinal cord from degenerative arthritis of the cervical spine.[4,5] There are frequently associated cervical spine pathologies such as intervertebral disc herniation, degenerative disc disease, and ossification of the posterior longitudinal ligament. These changes significantly narrow the spinal canal and cause compression of the cervical spinal cord. The common presentations of CSM may vary from slight dysesthesia and severe dysfunction, including gait instability, bladder dysfunction, and fine finger motor difficulties. Both in theory and in surgical techniques of CSM

has progressed by leaps and bounds in the past few decades, but many topics still remain controversial, such as the natural history of CSM, the optimal surgical timing, motion preservation technologies, clinical and imaging predictors of treatment outcome, and so on.[6-9]

[1] LongHua Hospital, Shanghai University of Traditional Chinese Medicine, Shanghai, China

[*] Mengchen Yin and Chongqing Xu are co–first authors of this article, contributing equally to the design and drafting of the manuscript.

Corresponding Author:
Wen Mo, Department of Orthopaedics, LongHua Hospital, Shanghai University of Traditional Chinese Medicine, Shanghai, China.
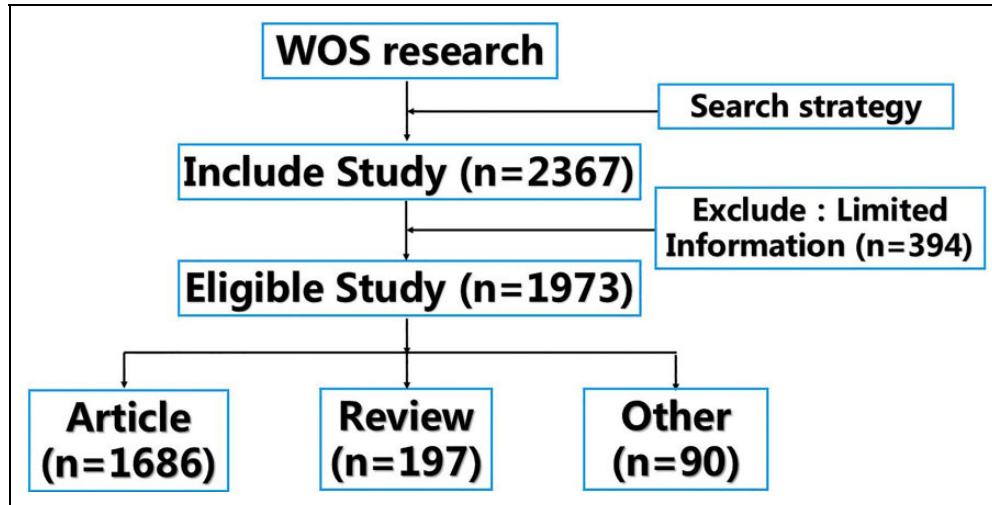Email: mw2218@126.com

Figure 1. Flow chart.

Bibliometrics is a special type of quantitative and qualitative analysis in knowledge fields. It comprehensively uses mathematics, statistics, philology, and other professional knowledge and methods to analyze the research achievement distribution of a current status. So it has played a great role in the past in governing policymaking and better understanding scientific fields.[10-13]

This study aimed to intuitively show the research framework, overall knowledge structure, and development trends of the field of CSM. Hopefully, this study will help scientific researchers better understand the research status and frontier trends. Furthermore, the results can also provide useful information and references for further investigation and publication.

Materials and Methods

Search Strategy and Refined Data

The data for this study was collected from the Web of Science (WOS) and its Core Collection. WOS is a most widely accepted and suitable database for the subsequent bibliometric analysis of scientific publications due to its strict evaluation process and the most influential and credible information it could provide.

The literature search was also limited to articles that were published from January 1, 2000, until November 1, 2019 (a span of 20 years). The search terms were integrated as follows: *cervical myeloradiculopathy* OR *cervical myelopathy* OR *cervical spondylotic myelopathy*. Original articles were included in this study, while letters, editorials, basic research articles, and corrections were exclude in our finalized data set. To perfect the research, 2 independent researchers reviewed and evaluated the cited articles, respectively. Any different opinions were discussed until consensus was reached.

Data Analysis

All data was extracted and imported into Microsoft Excel 2017 (Microsoft). Annual trends of publications, distribution,
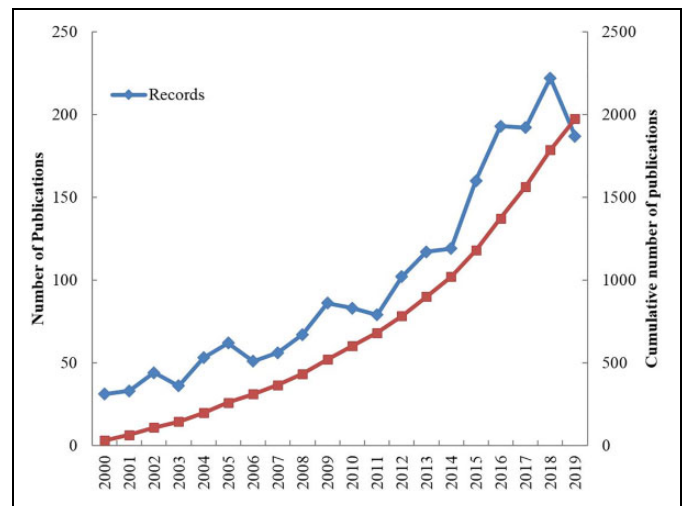

Figure 2. The annual trends of publications.

Table 1. Top 5 Countries Contributed to Research Publications in the Cervical Spondylotic Myelopathy Field.

Rank	Country	Number	Percentage	H-index
1	USA	529	26.81	50
2	Japan	490	24.84	49
3	China	346	17.54	29
4	Canada	143	7.25	31
5	India	97	4.92	17

citation and H-Index status, co-authorship status, research hotspots, and co-citation status were analyzed. All statistical analyses were performed using SPSS version 20.0 (SPSS Inc). Statistical significance was considered at $P < .05$. VOS viewer (Eck and Waltman) and Citespace (Chaomei Chen) are used to quantify information, visualize co-occurrence networks utilizing various layouts, and create timeline view of the keywords.[14-16]
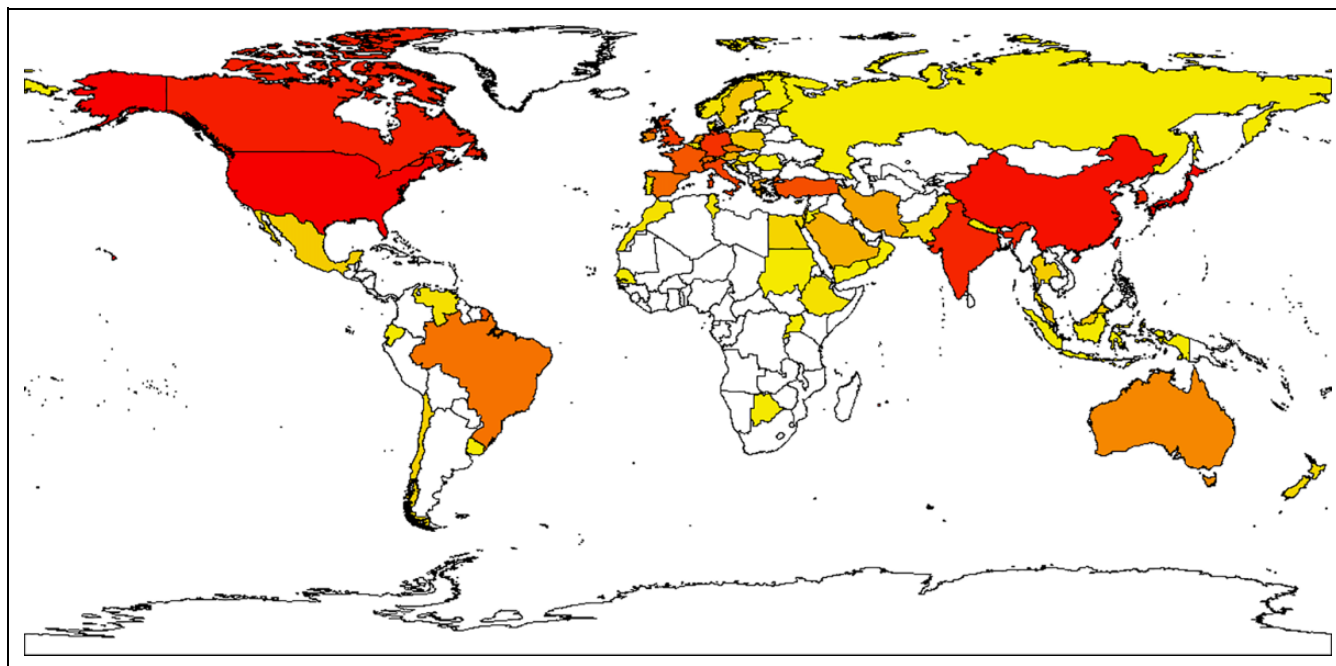
Figure 3. Map of worldwide research productivity.

Results

The Current Status and Distribution of Study

A total of 2367 articles on CSM were identified in the WOS database as a result of the search. With an additional manual screening according to the inclusion criteria, a total of 1973 articles were analyzed finally. The selection flow chart is shown in Figure 1. Thirty-one articles were published in 2000, and the growth was found in the following years. There was a peak in the number of studies from 2016 to 2019. A total of 222 articles were published in 2018, the highest number in all years. Overall, there was an upward trend with a stable rise of the number of publications, indicating more and more efforts and exploration have been made on CSM. Figure 2 plots the annual trends of publications. A total of 68 countries contributed to the field of CSM research. But the majority of the papers were published in only a few countries. There were 1605 papers (81.35%) published in the top 5 countries, and most of the studies were from North America and Asia. The United States published the largest number of articles (529, 26.81%), followed by Japan (490, 24.84%), China (346, 17.54%), Canada (143, 7.25%), and India (97, 4.92%). H-index is a reliable and authentic parameter for academic evaluation. The United States had the highest H-index (59), followed by Japan (49), Canada (31), China (29), and India (17; Table 1). Figure 3 shows a map of worldwide research productivity. There was emerging enthusiasm for research on CSM worldwide, with more publications concentrated in Asian and North American countries during recent decades.

All studies were published in 322 journals. Only 24 (7.4%) journals published more than 15 papers. The top 5 journals that

Table 2. Top 5 Journals in the Cervical Spondylotic Myelopathy Field.

Rank	Journal	Number	Percentage
1	*Spine*	296	15.00
2	*European Spine Journal*	143	7.25
3	*Journal of Neurosurgery Spine*	129	6.54
4	*World Neurosurgery*	92	4.66
5	*Neurosurgery*	64	3.24

Table 3. Top 5 Productive Institutions in the Cervical Spondylotic Myelopathy Field.

Rank	Institution (Country)	Number	Percentage
1	University of Toronto (Canada)	118	5.98
2	University Health Network Toronto (Canada)	105	5.32
3	University of California System (USA)	65	3.29
4	PLA Second Military Medical University (China)	49	2.48
5	Jefferson University (USA)	43	2.18

published the most papers are showed in Table 2. The journal with the greatest number of publications was *Spine*, with a total of 296 (15%) papers. At the second position was *European Spine Journal* with 143 (7.25%) papers, followed by *Journal of Neurosurgery Spine* with 129 (6.53%), *World Neurosurgery* with 92 (4.66%), and *Neurosurgery* with 64 (3.24%). The 5 journals account for 36.7% of all the papers.

The top 5 most productive institutions in the CSM field are summarized in Table 3. University of Toronto published the largest number of articles (118, 5.98%), followed by University

Table 4. Top 5 Productive Authors in the Cervical Spondylotic Myelopathy Field.

Rank	Institution (Country)	Number	Percentage	Affiliation
1	M. G. Fehlings (Canada)	106	5.37	Division of Neurosurgery, Department of Surgery, Toronto Western Hospital, University of Toronto, Toronto, Canada
2	B. Kopjar (USA)	32	1.62	Department of Health Services, University of Washington, Seattle, WA, USA
3	L. Tetreault (Canada)	31	1.57	Division of Neurosurgery, University of Toronto, Toronto Western Hospital, Toronto, Canada
4	A. Okawa (Japan)	28	1.42	Department of Orthopaedics, Graduate School, Tokyo Medical and Dental University, Tokyo, Japan
5	A. R. VACCARO (USA)	28	1.42	Department of Orthopedic Surgery, The Rothman Institute at Thomas Jefferson University, Philadelphia, PA, USA

Table 5. Top 10 Cited Articles in the Cervical Spondylotic Myelopathy Field.

Rank	Year	Title	Author	Journal	Citation
1	2001	Interobserver and intraobserver reliability of the Japanese Orthopaedic Association scoring system for evaluation of cervical compression myelopathy	Yonenobu K et al	*Spine*	221
2	2003	C5 palsy after decompression surgery for cervical myelopathy—review of the literature	Sakaura H et al	*Spine*	213
3	2001	Long-term results of double-door laminoplasty for cervical stenotic myelopathy	Seichi A et al	*Spine*	208
4	2006	Long-term results of expansive open-door laminoplasty for cervical myelopathy—average 14-year follow-up study	Chiba K et al	*Spine*	206
5	2001	Subtotal corpectomy versus laminoplasty for multilevel cervical spondylotic myelopathy—a long-term follow-up study over 10 years	Wada E et al	*Spine*	204
6	2003	Local kyphosis reduces surgical outcomes of expansive open-door laminoplasty for cervical spondylotic myelopathy	Suda K et al	*Spine*	197
7	2002	Long-term results of expansive laminoplasty for ossification of the posterior longitudinal ligament of the cervical spine: more than 10 years follow up	Iwasaki M et al	*Journal of Neurosurgery*	178
8	2001	Laminoplasty versus laminectomy and fusion for multilevel cervical myelopathy—an independent matched cohort analysis	Heller JG et al	*Spine*	174
9	2002	Corpectomy versus laminoplasty for multilevel cervical myelopathy—an independent matched-cohort analysis	Edwards CC et al	*Spine*	163
10	2001	Correlation between operative outcomes of cervical compression myelopathy and MRI of the spinal cord	Morio Y et al	*Spine*	160

Health Network Toronto (105, 5.32%), University of California System (65, 3.29%), PLA Second Military Medical University (49, 2.48%), and Jefferson University (43, 2.18%).

The top 5 most productive authors in the CSM field are shown in Table 4. M. G. Fehlings published the largest number of articles (106, 5.37%), followed by B. Kopjar (32, 1.62%), L. Tetreault (31, 1.57%), A. Okawa (28, 1.42%), and A. R. Vaccaro (28, 1.42%). Two of them were from Canada, two were from the United States, and the other one was from Japan.

Table 5 shows the top 10 cited articles in terms of title, journal, authors, years, and citation numbers. The highest number of citations for an article in the field of CSM research was 221. Nine of these top 10 cited articles were published in the journal *Spine*, while the remaining only one article was published in the *Journal of Neurosurgery Spine*. Among them, one study was published in 2006, while the remaining 9 articles were published in from 2001 to 2005. All the 10 papers were co-authored. The average number of authors is 5.3.

The Co-Authorship Analysis

Co-authorship analysis is an important form to reflect the degree of communication in this field. The links in the map between nodes represents the cooperative relationships. The distance between the nodes and the thickness of the links reveal the level of cooperation among influential countries, institutes, and authors. Figure 4 to 6 display the country, institute, and authors' co-authorship network of publications, respectively. There are some intersection among these countries, institutes, and authors. While the link strength was not high, the results showed that the cooperation between the countries, institutes, and authors was relatively weak, indicating that international collaboration needs to be strengthened.

The Keywords Analysis of Research Hotspots on Study

Keywords co-occurrence can effectively reflect the research hotspots and provide support for the research. From Figure 7,
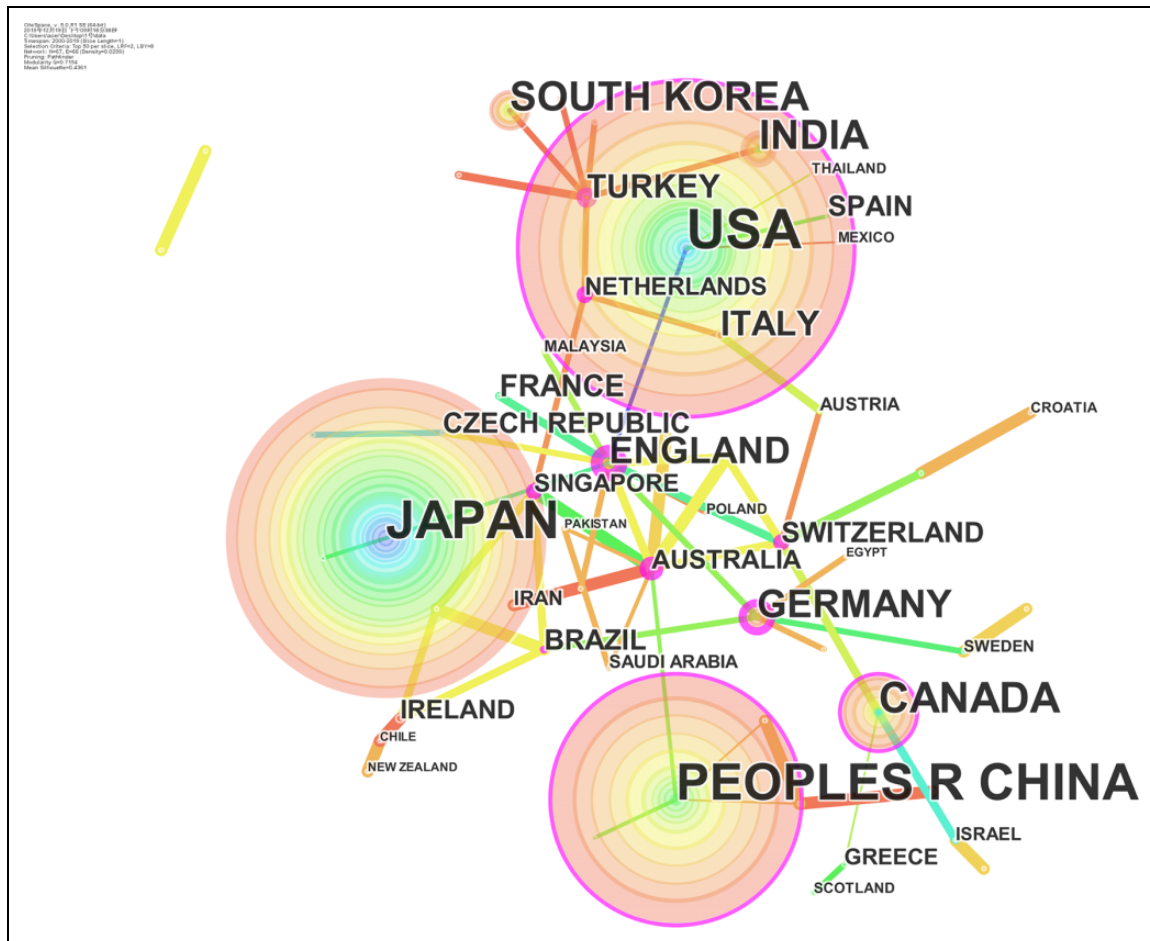
Figure 4. The country co-authorship network of publication.

we can see the visualized research focuses. The bigger nodes and words generally show a larger weight of the keyword. The shorter distance reveals a stronger relation between 2 nodes. The thicker line indicates a more frequent co-occurrence of the 2 keywords. In Figure 7, we can see the visualized research focuses. In addition to "cervical spondylotic myelopathy" and "cervical myelopathy," the other core keywords were scattered and link strength was not high. Table 6 shows the 15 meaningful keywords with the strongest citation burst, which represented the research frontiers of the CSM field. The red and blue bars represent the frequently and infrequently cited keywords, respectively. Table 6 indicated that cervical sagittal alignment, predictive factor, diffusion tensor imaging, and the natural history of CSM are the research hotspots in the recent years.

Discussion

Bibliometric analysis is a tool to quantify the characteristics and scholarly impact of citation classics. Understanding the characteristics of highly cited studies in a journal may help authors who wish to submit and publish effectively. It is the most widely accepted method to assess the merits of a specific field.[17-19] To the best of our knowledge, the current study is the first to analyze the quality and quantity of researches using bibliometric analysis and visualization tool in the field of CSM. CSM research has made great progress in recent years. To guarantee the comprehensiveness of the publication, we conducted a systematic literature search in the WOS database, because WOS could offer a powerful analysis of data from various aspects with a high and powerful recognition and a uniform citation rate.

In our study, the result showed a stable rise in the number of CSM publications in recent years, especially from 2011 to 2018. This trend suggests that the development of CSM research has a rapid stage of progress and attracted more attention in the global medical community. The study found that 81.36% of total articles were published by the top 5 productive countries (the United States, Japan, China, Canada, and India), and the top productive institutions were all from the 5 countries in the field of CSM. It indicated that worldwide research results of CSM were concentrated in some countries and continents. Incidence of disease, population size, and research status have played an important role in the differences of scientific output among countries. The number of citations can reflect the quality of a paper. H-index is a reliable and authentic parameter for academic evaluation of the core scientists. Among the top 5
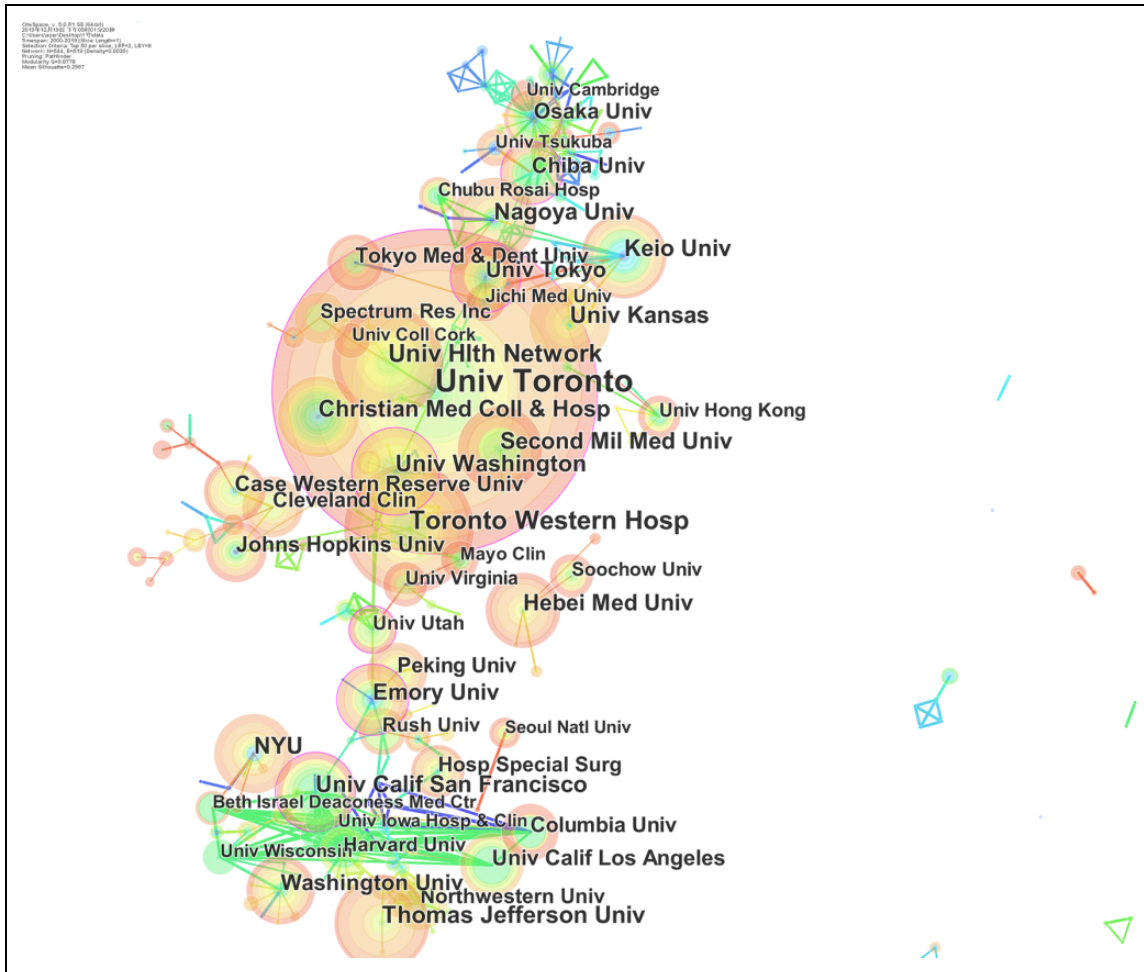
Figure 5. The institute co-authorship network of publications.

most productive countries, the United States, Japan, and Canada made up all the top 10 cited articles. There was no article from China and India in the top 10 cited articles. And the citation frequency and the H-index of China and India were relatively low. From the above-mentioned data, the United States and Japan have been the leaders in the field of CSM with the largest quantities and the highest qualities, which also implies that the quality of the publications in China and India needs improvement. But the influence of CSM research from China and India are more significant than the other counties and cannot be ignored. Regarding the productive journals in the field of CSM, *Spine* has the greatest number of publications with a total of 296 (15%) papers. In addition, *Spine* has published 9 of 10 top cited articles. There is no doubt that *Spine* is the most recognized journal, and articles published in *Spine* may be more influential in the field of CSM research.

There are some possible reasons for the United States and Japan's great contributions to the field of CSM. One of the main reasons is the rapid development of economy and technology. In addition, substantial research funds are invested in medical research to increase the quality of researches in the United States and Japan.[20-22] Although China and India has

increasing contributions to the field of CSM, several current problems should be recognized. First, China and India have an advantage in recruitment of participants because of the largest populations in the world and high prevalence of spinal disorders, but they are still developing countries with relatively backward technological strength. Second, the amount of government funds is still relatively low. For example, Chinese government funds in medical research only account for 20% to 30% of the total governments funds.[23] Third, most individuals do not have a Western-style health care, which helps participants to join in multicenter studies, far from the modernization level to publish high-quality scientific articles.

The ultimate aims of surgical intervention for CSM are to provide adequate decompression of the spinal cord and ensure mechanical stability. Preoperative consideration should be given to a number of factors, including age, cervical deformity, OPLL (ossification of the posterior longitudinal ligament), degree of compression, and so on. Spinal cord decompression can be performed via anterior, posterior, or combined approaches, which has been a classic topic of debate in spine surgery. Due to its heterogeneity, there exists a number of approaches and techniques, including ACDF (anterior cervical
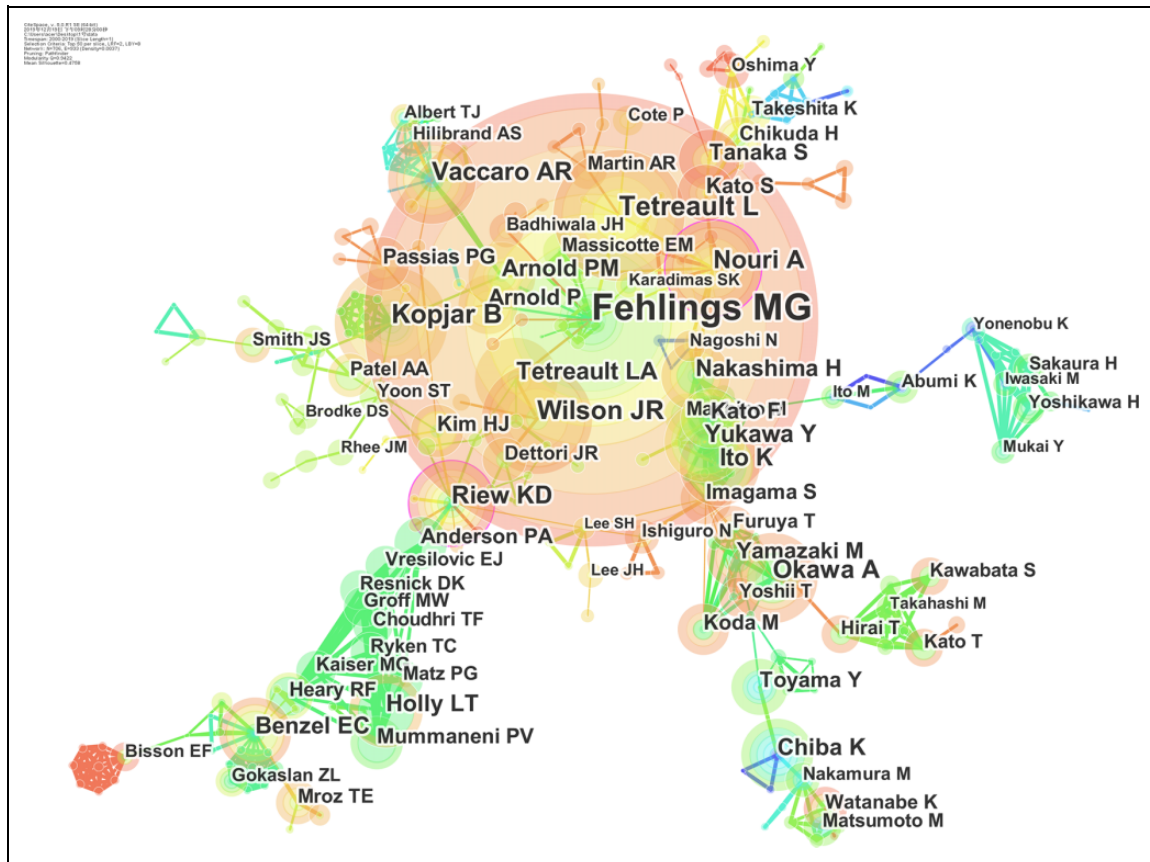
Figure 6. The author co-authorship network of publications.

discectomy and fusion), ACCF (anterior cervical corpectomy and fusion), cervical artificial disc, hybrid procedures, as well as posterior laminectomy and laminoplasty.[24-28] The decision making in choosing the best techniques depends on individual cases, surgeon's abilities, and experience.

Our study indicated that cervical sagittal alignment, predictive factor, diffusion tensor imaging, and the natural history of CSM are the research hotspots in the recent years. For the evaluation of the balance state of the cervical spine, the sagittal alignment is usually taken as the reference basis. The cervical spine sequence of the lordosis is considered as the balance state. The sequence of kyphosis is considered as an abnormal state, which has adverse effects on the recovery of the neurological function after the operation of CSM. However, at present, it is believed that the sagittal alignment with single slight kyphosis or straightness can no longer be regarded as a rational manifestation of cervical spondylosis, and the overall sagittal balance has become an important factors affecting the treatment outcome of CSM. According to study of Tetreault and Karpova, symptomatic patients with cervical spondylosis mean long-term compression of the spinal cord may indicate the occurrence of spinal degeneration and further change of spinal sagittal balance and portend the worse prognosis of CSM patients. It was found that whether the C2-7 Cobb angle/T1 slope ratio was too large or too small was related to the functional recovery.[29,30] Tang found that when CSVA (cervical

sagittal vertical axis) was more than 40 mm, the patient's health quality of life was lower, which indicated that the greater CSVA would be produced when the sagittal balance of the cervical spine was decompensated.[31] Knott et al believe that T1 slope is an important parameter, when T1 slope was >25° or <13° may indicate the sagittal imbalance, and a satisfactory surgical outcome can be achieved with T1 slope between 13° and 25°.[32] In general, the significance of sagittal balance in CSM has received more and more attention, but larger samples and further studies are still needed.

The pattern of progression in CSM is not well defined. Up to now, there are 2 views on the natural history of CSM. Some scholars think that CSM is a kind of malignant disease. And many reports of the natural history suggest that CSM is a relatively benign disorder and neurological dysfunction of CSM can be in a static state for a long time or improved slightly than to deteriorate. Moderate-strength evidence related to the natural history of CSM suggests that 20% to 60% of patients will deteriorate neurologically over time without surgical intervention. Low-strength evidence indicated that the area of circumferential compression is associated with deteriorating neurological symptoms.[6,33] CSM has unique pathobiological mechanisms that mainly remain unexplored. Although the natural history of CSM can be mixed, surgical intervention eliminates the chances of the neurological deterioration. In addition, careful multicenter clinical registries are needed to define the

Figure 7. Keywords co-occurrence network of publications.

incidence and prevalence of CSM more accurately, to track the natural history of this condition, and to explore the potential risk factors of the disease progression.[34] More recently, advanced MRI (magnetic resonance imaging) techniques that interrogate specific aspects of microstructure such as axonal integrity, demyelination, and tract-specific atrophy have been used. Diffusion tensor imaging (DTI) is a new MRI technique that emerged in recent years. DTI can reveal the function of living tissues by quantifying the diffusion of water molecules with advantages of high sensitivity and quantitative features.[35] Zheng et al reported that 61 patients were divided into 4 subgroups according to JOA (Japanese Orthopaedic Association) recovery rate. Apparent diffusion coefficient, mean diffusivity, axial diffusivity, and radial diffusivity values were significantly correlated with JOA recovery rate.[36] Dong et al reported 110 patients were enrolled to compare DTI parameters of the spinal cord between patients with CSM and normal subjects. There were significant differences in DTI parameters of the spinal cord in the 2 groups. The FA values at the maximal

compression level were significantly associated with the mJOA (modified JOA) score preoperative.[37] So, these evaluation metrics may reflect the pathologic conditions of the spinal cord quantitatively, and potentially evaluate the functional status of spinal cords. These suggest DTI may play a significant role in diagnosing and predicting the development and surgical outcomes for patients with CSM.

Given that CSM is a prevalent cause of spinal cord injury, and since surgery is often an appropriate intervention, it would be useful to identify the most important predictors of outcome for patients undergoing surgical treatment. Holly et al conducted a systematic review and found that the most common predictors of surgical outcome were age, duration of symptoms, and severity of myelopathy.[38] Karpova et al showed that age and baseline mJOA scores were highly predictive of surgical outcome.[30] The degree of spinal cord compression on MRI was found to correlate with functional status at the time of presentation and age of the patient. Tetreault et al drew a conclusion that the most important predictive factors were

Table 6. Top 15 Meaningful Keywords With Strongest Citation Bursts.

No.	Keywords	Strength	Begin	End	2000-2019
1	Instability	5.5884	2000	2004	
2	Calcification	2.9856	2001	2007	
3	Botulinum toxin	4.8817	2002	2008	
4	Stenotic myelopathy	5.9364	2003	2012	
5	Posterior decompression	3.31	2003	2008	
6	MRI image	3.6018	2007	2014	
7	Dysphagia	3.9623	2014	2017	
8	Prediction	4.4929	2014	2019	
9	Neck Disability Index	4.1333	2014	2015	
10	C5 palsy	6.4757	2014	2017	
11	Sagittal alignment	3.438	2016	2019	
12	Predictive factor	3.2714	2016	2019	
13	Diffusion tensor imaging	4.2761	2016	2019	
14	Natural history	3.3229	2017	2019	
15	T1 slope	2.8954	2017	2019	

[a]The red and blue bars represent the frequently and infrequently cited keywords, respectively.

preoperative severity and duration of symptoms.[39] However, controversy still remains. In addition, many other signs, symptoms, comorbidities, and smoking status are important factors to influence the operative efficacy.

This study has some limitations. First, bibliometric analyses only contain the published literature in WOS database, and the unpublished and non-WOS-cited journals were not included. In addition, the delay of the indexation may account for the slight difference in the results retrieved. Second, all citations were treated in the same way whether it was cited for its positive contribution or for its negative impact or poor quality. Also the authors might tend to cite papers from the journals in which they hoped to publish their research. So, bibliometric analyses have the potential to generate misleading and biased results. Third, despite our additional manual screening, selection bias was inevitable. Analyses can only provide a rough overview of trends in research and publishing. The input data might still have included irrelevant or duplicate titles and have missed pertinent publications. Despite these limitations, our study provided some insights into the characteristics of researches and citation of articles published in the field of CSM.

Conclusions

In this study, bibliometric analysis was performed on the quantity, quality, and research hotspots of publications in the field of CSM. The number of publications showed an upward trend with a stable rise in recent years. The distribution of research was imbalanced. Most of publications are limited to a few countries and institutions with relatively weak interaction. The United States, Canada, Japan, China, and India have made significant contributions to the field of CSM. The United States is the country with the highest productivity, not only in quality but also in quantity. However, the contributions of China and India cannot be underestimated. Cervical sagittal alignment,

predictive factor, diffusion tensor imaging, and the natural history of CSM are the research hotspots in the recent years.

Author Contributions

MCY and CQX are co–first authors of this article, contributing equally to the design, conduct of the trials, and drafting the manuscript. All authors participated in the design of the study and performed the trial. WM is corresponding author of this manuscript, supervising and coordinating the clinical trial. MCY, JMM, and JY were responsible for recruiting the participants. MCY and CQX participated in the statistical design. All authors read and approved the final manuscript.

Declaration of Conflicting Interests

Funding

ORCID iD

Mengchen Yin, MD https://orcid.org/0000-0001-7404-1495

References

1. Fehlings MG, Tetreault LA, Wilson JR, Skelly AC. Cervical spondylotic myelopathy: current state of the art and future directions. *Spine (Phila Pa 1976)*. 2013;38(22 suppl):S1-S8. doi:10.1097/BRS.0b013e3182a7e9e0

2. Nouri A, Tetreault L, Singh A, Karadimas SK, Fehlings MG. Degenerative cervical myelopathy: epidemiology, genetics, and pathogenesis. *Spine (Phila Pa 1976)*. 2015;40:E675-E693. doi:10.1097/BRS.0000000000000913

3. Fehlings MG, Tetreault L, Nater A, et al. The aging of the global population: the changing epidemiology of disease and spinal disorders. *Neurosurgery*. 2015;77(suppl 4):S1-S5. doi:10.1227/NEU.0000000000000953

4. Karadimas SK, Gatzounis G, Fehlings MG. Pathobiology of cervical spondylotic myelopathy. *Eur Spine J*. 2015;24(suppl 2): 132-138. doi:10.1007/s00586-014-3264-4

5. Kalsi-Ryan S, Karadimas SK, Fehlings MG. Cervical spondylotic myelopathy: the clinical phenomenon and the current pathobiology of an increasingly prevalent and devastating disorder. *Neuroscientist*. 2013;19:409-421. doi:10.1177/1073858412467377

6. Karadimas SK, Erwin WM, Ely CG, Dettori JR, Fehlings MG. Pathophysiology and natural history of cervical spondylotic myelopathy. *Spine (Phila Pa 1976)*. 2013;38(22 suppl):S21-S36. doi: 10.1097/BRS.0b013e3182a7f2c3

7. Rhee J, Tetreault LA, Chapman JR, et al. Nonoperative versus operative management for the treatment degenerative cervical myelopathy: an updated systematic review. *Global Spine J*. 2017;7(3 suppl):35S-41S. doi:10.1177/2192568217703083

8. Tetreault LA, Rhee J, Prather H, et al. Change in function, pain, and quality of life following structured nonoperative treatment in patients with degenerative cervical myelopathy: a systematic review. *Global Spine J*. 2017;7:42S-52S. doi:10.1177/21925 68217700397

9. Fehlings MG, Wilson JR, Kopjar B, et al. Efficacy and safety of surgical decompression in patients with cervical spondylotic myelopathy: results of the AOSpine North America prospective multi-center study. *J Bone Joint Surg Am*. 2013;95:1651-1658. doi:10.2106/JBJS.L.00589

10. Ergul S, Ardahan M, Temel AB, Yildirim BO. Bibliometric review of references of nursing research papers during the decade 1994-2003 in Turkey. *Int Nurs Rev*. 2010;57:49-55. doi:10.1111/ j.1466-7657.2009.00770.x

11. Zhang TS, Qin HL, Wang T, et al. Global publication trends and research hotspots of nonalcoholic fatty liver disease: a bibliometric analysis and systematic review. *Springerplus*. 2015;4: 776. doi:10.1186/s40064-015-1542-1

12. Sun J, Wang MH, Ho YS. A historical review and bibliometric analysis of research on estuary pollution. *Mar Pollut Bull*. 2012; 64:13-21. doi:10.1016/j.marpolbul.2011.10.034

13. Boyce R, Rosch R, Finlayson A, et al. Use of a bibliometric literature review to assess medical research capacity in post-conflict and developing countries: Somaliland 1991-2013. *Trop Med Int Health*. 2015;20:1507-1515. doi:10.1111/tmi.12590

14. van Eck NJ, Waltman L. Software survey: VOSviewer, a computer program for bibliometric mapping. *Scientometrics*. 2010;84: 523-538. doi:10.1007/s11192-009-0146-3

15. Fajardo-Ortiz D, Duran L, Moreno L, Ochoa H, Castano VM. Mapping knowledge translation and innovation processes in cancer drug development: the case of liposomal doxorubicin. *J Transl Med*. 2014;12:227. doi:10.1186/s12967-014-0227-9

16. Chen C, Hu Z, Liu S, Tseng H. Emerging trends in regenerative medicine: a scientometric analysis in CiteSpace. *Expert Opin Biol Ther*. 2012;12:593-608. doi:10.1517/14712598.2012. 674507

17. Paris G, De Leo G, Menozzi P, Gatto M. Region-based citation bias in science. *Nature*. 1998;396:210. doi:10.1038/24249

18. Liu YH, Wang SQ, Xue JH, et al. Hundred top-cited articles focusing on acute kidney injury: a bibliometric analysis. *BMJ Open*. 2016;6:e011630. doi:10.1136/bmjopen-2016-011630

19. Allen L, Jones C, Dolby K, Lynn D, Walport M. Looking for landmarks: the role of expert review and bibliometric analysis in evaluating scientific publication outputs. *PLoS One*. 2009;4: e5910. doi:10.1371/journal.pone.0005910

20. Mei X, Zhu X, Zhang T, Jia Z, Wan C. Worldwide productivity in the hand and wrist literature: a bibliometric analysis of four highly cited subspecialty journals. *Int J Surg*. 2016;28:8-12. doi:10.1016/ j.ijsu.2016.02.029

21. Wei M, Wang W, Zhuang Y. Worldwide research productivity in the field of spine surgery: a 10-year bibliometric analysis. *Eur Spine J*. 2016;25:976-982. doi:10.1007/s00586-016-4442-3

22. Fan G, Han R, Zhang H, He S, Chen Z. Worldwide research productivity in the field of minimally invasive spine surgery: a 20-year survey of publication activities. *Spine (Phila Pa 1976)*. 2017;42:1717-1722. doi:10.1097/BRS.0000000000001393

23. Lin GX, Kotheeranurak V, Mahatthanatrakul A, et al. Worldwide research productivity in the field of full-endoscopic spine surgery: a bibliometric study. *Eur Spine J*. 2020;29:153-160. doi:10.1007/ s00586-019-06171-2

24. Fehlings MG, Barry S, Kopjar B, et al. Anterior versus posterior surgical approaches to treat cervical spondylotic myelopathy: outcomes of the prospective multicenter AOSpine North America CSM study in 264 patients. *Spine (Phila Pa 1976)*. 2013;38: 2247-2252. doi:10.1097/BRS.0000000000000047

25. Asher AL, Devin CJ, Kerezoudis P, et al. Comparison of outcomes following anterior vs posterior fusion surgery for patients with degenerative cervical myelopathy: an analysis from quality outcomes database. *Neurosurgery*. 2019;84:919-926. doi:10. 1093/neuros/nyy144

26. Kato S, Nouri A, Wu D, Nori S, Tetreault L, Fehlings MG. Comparison of anterior and posterior surgery for degenerative cervical myelopathy: an MRI-based propensity-score-matched analysis using data from the prospective multicenter AOSpine CSM North America and International Studies. *J Bone Joint Surg Am*. 2017; 99:1013-1021. doi:10.2106/JBJS.16.00882

27. Youssef JA, Heiner AD, Montgomery JR, et al. Outcomes of posterior cervical fusion and decompression: a systematic review and meta-analysis. *Spine J*. 2019;19:1714-1729. doi:10.1016/j. spinee.2019.04.019

28. Fehlings MG, Santaguida C, Tetreault L, et al. Laminectomy and fusion versus laminoplasty for the treatment of degenerative cervical myelopathy: results from the AOSpine North America and International prospective multicenter studies. *Spine J*. 2017;17: 102-108. doi:10.1016/j.spinee.2016.08.019

29. Tetreault LA, Kopjar B, Vaccaro A, et al. A clinical prediction model to determine outcomes in patients with cervical spondylotic myelopathy undergoing surgical treatment: data from the prospective, multi-center AOSpine North America study. *J Bone Joint Surg Am*. 2013;95:1659-1666. doi:10.2106/JBJS. L.01323

30. Karpova A, Arun R, Davis AM, et al. Predictors of surgical outcome in cervical spondylotic myelopathy. *Spine (Phila Pa 1976)*. 2013;38:392-400. doi:10.1097/BRS.0b013e3182715bc3

31. Tang JA, Scheer JK, Smith JS, et al. The impact of standing regional cervical sagittal alignment on outcomes in posterior

cervical fusion surgery. *Neurosurgery*. 2015;76(suppl 1): S14-S21. doi:10.1227/01.neu.0000462074.66077.2b

32. Knott PT, Mardjetko SM, Techy F. The use of the T1 sagittal angle in predicting overall sagittal balance of the spine. *Spine J*. 2010;10:994-998. doi:10.1016/j.spinee.2010.08.031

33. Tetreault L, Goldstein CL, Arnold P, et al. Degenerative cervical myelopathy: a spectrum of related disorders affecting the aging spine. *Neurosurgery*. 2015;77(suppl 4):S51-S67. doi:10.1227/NEU.0000000000000951

34. Tetreault LA, Karadimas S, Wilson JR, et al. The natural history of degenerative cervical myelopathy and the rate of hospitalization following spinal cord injury: an updated systematic review. *Global Spine J*. 2017;7(3 suppl):28S-34S. doi:10.1177/2192568217700396

35. Nukala M, Abraham J, Khandige G, Shetty BK, Rao APA. Efficacy of diffusion tensor imaging in identification of degenerative cervical spondylotic myelopathy. *Eur J Radiol Open*. 2018;6:16-23. doi:10.1016/j.ejro.2018.08.006

36. Zheng W, Chen H, Wang N, et al. Application of diffusion tensor imaging cutoff value to evaluate the severity and postoperative neurologic recovery of cervical spondylotic myelopathy. *World Neurosurg*. 2018;118:e849-e855. doi:10.1016/j.wneu.2018.07.067

37. Dong F, Wu Y, Song P, et al. A preliminary study of 3.0-T magnetic resonance diffusion tensor imaging in cervical spondylotic myelopathy. *Eur Spine J*. 2018;27:1839-1845. doi:10.1007/s00586-018-5579-z

38. Holly LT, Matz PG, Anderson PA, et al. Clinical prognostic indicators of surgical outcome in cervical spondylotic myelopathy. *J Neurosurg Spine*. 2009;11:112-118. doi:10.3171/2009.1.SPINE08718

39. Tetreault LA, Karpova A, Fehlings MG. Predictors of outcome in patients with degenerative cervical spondylotic myelopathy undergoing surgical treatment: results of a systematic review. *Eur Spine J*. 2015;24(suppl 2):236-251. doi:10.1007/s00586-013-2658-z