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Trends of spinal tuberculosis research (1994–2015)

A bibliometric study

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Abstract

Background: Spinal tuberculosis is the most common form of skeletal tuberculosis. However, there were limited data to evaluate the trend of spinal tuberculosis research. This study aims to investigate the trend of spinal tuberculosis research and compare the contribution of research from different countries and authors.

Methods: Spinal tuberculosis-related publications from 1994 to 2015 were retrieved from the Web of Science database. Excel 2013, GraphPad Prism 5, and VOSviewer software were used to analyze the search results for number of publications, cited frequency, H-index, and country contributions.

Results: A total of 1558 papers were identified and were cited 16,152 times as of January 25, 2016. The United States accounted for 15.1% of the articles, 22.3% of the citations, and the highest H-index (33). China ranked third in total number of articles, fifth in citation frequency (815), and ranked seventh in H-index (13). The journal *Spine* (IF 2.297) had the highest number of publications. The author Jain A.K. has published the most papers in this field (20). The article titled "Tuberculosis of the spine: Controversies and a new challenge" was the most popular article and cited a total of 1138 times. The keyword "disease" was mentioned the most for 118 times and the word "bone fusion" was the latest hotspot by 2015.

Conclusion: Literature growth in spinal tuberculosis is slowly expanding. Although publications from China are increasing, the quality of the articles still requires improvements. Meanwhile, the United States continues to be the largest contributor in the field of spinal tuberculosis. According to our bibliometric study, bone fusion may be an emerging topic within spinal tuberculosis research and is something that should be closely observed.

Abbreviation: NEJM = New England Journal of Medicine.

Keywords: bibliometric, citation, H-index, spinal tuberculosis, VOSviewer

1. Introduction

Spinal tuberculosis is a complication that can occur from tuberculosis of the lungs.[1] It causes destruction of vertebral bodies, intervertebral discs, and may give rise to paravertebral or psoas abscesses.[2] Spinal tuberculosis is a very dangerous type of skeletal tuberculosis as it can be associated with neurologic deficit due to compression of adjacent neural structures and significant spinal deformity.[3] An article published by Carlos Pigrau-Serrallach reported that bone and joint tuberculosis currently accounted for 2.2% to 4.7% of all tuberculosis cases in Europe and 10% to 15% of extra pulmonary tuberculosis cases in the United States. In developing countries, particularly Asia, the incidence of extra pulmonary tuberculosis can be as high as 15% to 20%.[4] Additionally, rapid progress regarding spinal tuberculosis has not been well studied. Thus, it is necessary to monitor the global spinal tuberculosis research. Currently, no such analysis of the research progression for spinal tuberculosis has been established.

Bibliometrics is an important tool to measure scientific output of an individual, institution, or country using relevant parameters including quantity, impact factor, and citation of published articles over time.[5] Bibliometrics uses the literature system and literature metrology characteristics as research objects and analyzes the literature quantitatively and qualitatively.[6] It can provide an access to characterize the current research status in a certain field[7] and has played a fundamental role in the past to govern policymaking, clinical guideline, and research trend in

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YW and QW contributed equally to this work.

Conceived and designed the experiments: XZ and ML; performed the experiments: YW and QW; analyzed the data: CY and ZC, contributed reagents/materials/analysis tools: YB and XZ; wrote the paper: YW and RZ.

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diabetes,[8] cardiovascular disease,[9] respiratory medicine,[10] and gastrointestinal diseases.[11]

This paper presents a novel study employing the bibliometrics method to analyze spinal tuberculosis publications retrieved on the Web of Science (Thomson Reuters Company) database from 1994 to 2015. The trend of spinal tuberculosis research could be better understood and the next possible hotspot in this field was found.

2. Materials and methods

2.1. Sources of the data and search strategy

A literature search was performed in the Web of Science in January 2016. The databases included Science Citation Index Expanded, Social Sciences Index, and Arts and Humanities Citation Index. Ethical approval was not necessary, because the data were downloaded from the public databases. There were no ethical questions about the data.

Terms used during the search were: Theme = ((Spinal Tuberculosis) OR (Tuberculosis, Spinal) OR (Pott AND Disease) OR (Pott's AND Disease) OR (Pott's AND Disease) OR (Pott's Paraplegia) OR (Potts Disease)) AND publishing year = (1994–2015).

Refining for certain country/region: the country/region was selected as "the United States" or "India" or "China" or other countries.

2.2. Data collection

The data entry and collecting were verified by two authors (YW and QW). The txt data downloaded from Web of Science were imported into Microsoft Excel 2013, GraphPad Prism 5, and VOSviewer. The data were analyzed both quantitatively and qualitatively.

2.3. Statistical methods

Web of Science was used to analyze the characteristics of the publications, including countries, regions, publication time, authors, citation frequency, and H-index. The relative research interest was calculated as the number of weighted publications per year divided by the number of all weighted publications across all the disciplines per year. To improve upon simpler measures such as the total number of citations or publications, H-index is designed as a measure of scientific research impact. The index of H means a scholar has published H papers each of which has been cited in other papers at least H times. And thus, the H-index reflects both the number of publications and the number of citations per publication.[12]

GraphPad Prism 5 (GraphPad Software Inc., San Diego, CA) was used to analyze the time trend of the publications. The logistic regression model: $f(x) = c/[1 + a \times \exp(-b \times x)]$ was used to calculate the cumulative volume and to predict future trend of papers in this field. The inflection point of the logistic curve was the time when the growth rate of papers moved from positive to negative. The formula $T = \ln a/b$ was used to generate the point.

VOSviewer (Leiden University, Leiden, Netherlands) was used to analyze the relations among highly cited references and productive authors. It was commonly used for co-citation network analysis and visualization.[13] The VOSviewer was also used to generate the knowledge maps of countries, institutions, cited authors, cited journals, co-words, and cited references related to spinal tuberculosis research. Research is a team work and all the authors and institutions contributed to the paper. So all the authors and institutions of papers were analyzed in the software.

3. Results

3.1. Countries/regions contributing to global publications and growing trends

A total of 1558 articles met the searching criteria from 1994 to 2015 (Fig. 1A). One thousand two hundred ninety-eight publications were identified from Science Citation Index Expanded, and 773 were identified from Social Sciences Index and Arts and Humanities Citation Index database. The United States published the most papers (234, 15.02%), followed by India (226, 14.51%) and China (196, 12.64%) (Fig. 1B). China published the most papers per year after 2012 (Fig. 1C).

Model fitting curves of growth trends of spinal tuberculosis publications showed that the inflection point (growth rate of papers from positive to negative) globally was in 2010 (Fig. 2A). The inflection point for the United States (Fig. 2B) and India were 2009 and 2011, respectively (Fig. 2C). The inflection point for China was predicted to be at 2040 (Fig. 2D).

3.2. Citation and H-index analysis

According to our analysis of the Web of Science database, all articles related to spinal tuberculosis had been cited 18,217 times since 1994 (12,336 times without self-citations). The cited frequency per paper was 10.37 times. The number of citations of papers from the United States was 4050, accounting for 22.23% of the total citations. The H-index of papers from the United States was 33. India ranked the second with the citation frequency of 2442 and the H-index of 25. Though the number of publications from China ranked the third, the citation frequency and H-index ranked the fifth and seventh, respectively (Fig. 3A).

3.3. Distribution of published journals on spinal tuberculosis

Over 72 journals have published more than 4 papers in the field of spinal tuberculosis, accounting for 52.82% of all published literature relating to the field. The top 20 journals that published the most papers are shown in Fig. 3B. The journal *Spine* published the most papers (67). There were 2 case reports, 3 letters, and 3 reviews in the NEJM (*New England Journal of Medicine)* (IF = 55.876, 2016) on spinal tuberculosis. Three reviews were in the Lancet (IF = 45.217, 2016).

3.4. Distribution of authors on spinal tuberculosis

Over 5702 authors contributed over a total of 1558 papers relating to spinal tuberculosis. Jain A.K. published the most papers in this field (20 papers), followed by Zhang H.Q. with 19 publication and Rajasekaran S. with 16 publications (Fig. 3C).

3.5. References of papers on spinal tuberculosis

The reference analysis is one of the most important indicators of bibliometrics. References of papers in the dataset were analyzed by VOSviewer, and the top 145 papers in the dataset were selected for analysis. The papers included in the analysis were divided into 5 clusters (Fig. 4A).

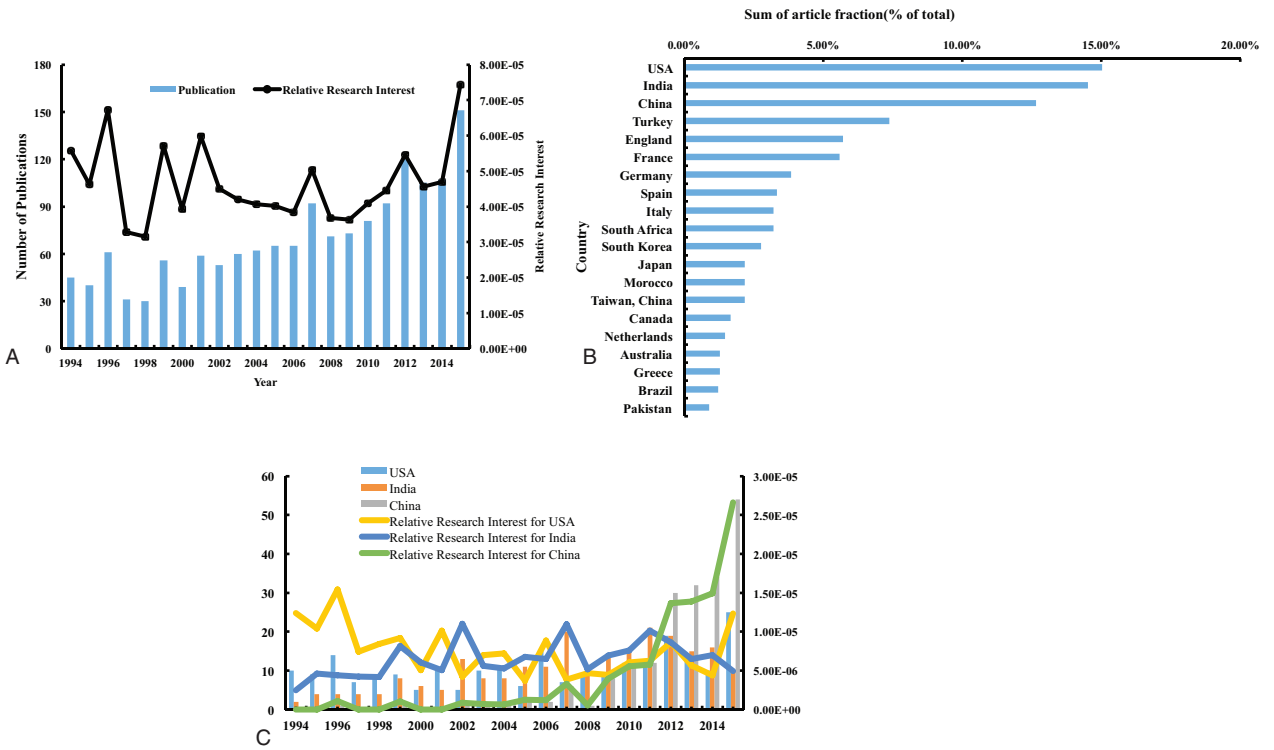

Figure 1. The figure shows the countries'/regions' contributions to spinal tuberculosis research. (A) The time curve of worldwide spinal tuberculosis publications. (B) The sum of spinal tuberculosis research-related article fractions (% of research from all regions) from the top 20 countries/regions. (C) The time curve of spinal tuberculosis articles from the United States, India, and China.

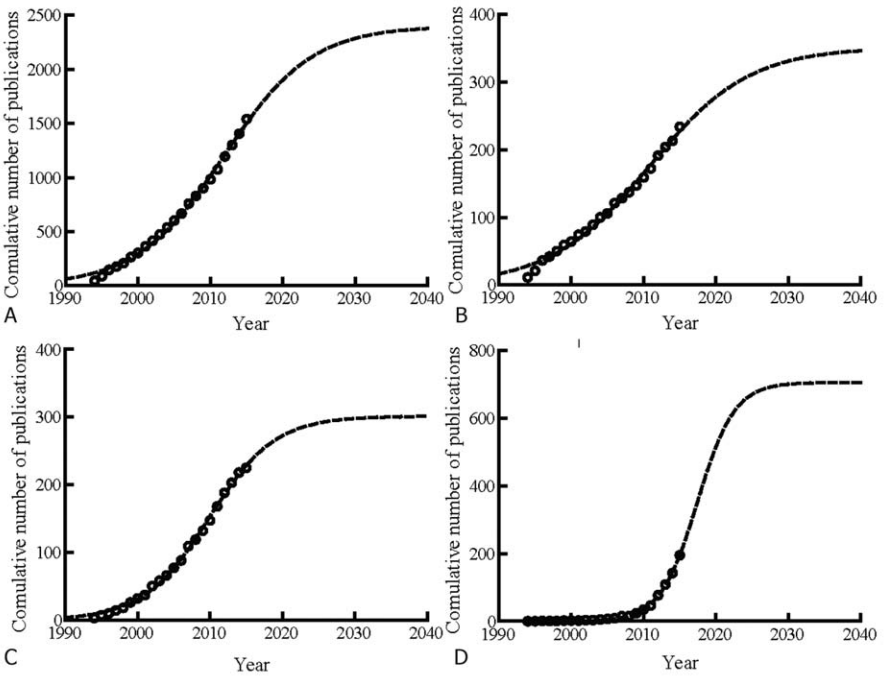

Figure 2. The figure shows model fitting curves of growth trends of spinal tuberculosis publications. (A) Global, (B) the United States, (C) India, and (D) China.

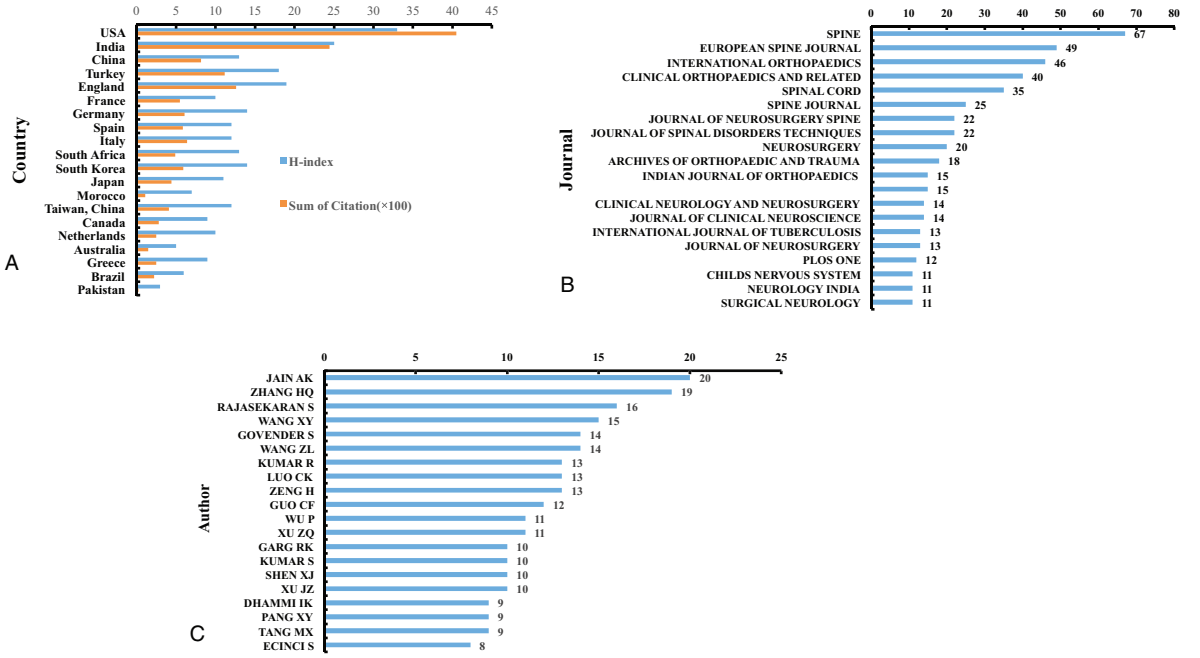

Figure 3. (A) Citation and H-index analysis of the top 20 countries/regions. (B) Distribution of the top 20 published journals on spinal tuberculosis. (C) Distribution of the top 20 authors on spinal tuberculosis.

The first cluster included 56 papers and focused mainly on the surgical treatment of spinal tuberculosis. The second cluster included 55 papers and focused on the medical treatment of spinal tuberculosis. The third cluster included 13 papers and was related to the follow-up of patients after undergoing different treatment modalities. The fourth cluster included 11 papers regarding the diagnosis of spinal tuberculosis. Lastly, the fifth cluster included 10 papers relating to the etiology of spinal tuberculosis (Fig. 4). (Supplemental Table 1, http://links.lww.com/MD/B291).

3.6. Hotspots of studies on spinal tuberculosis

Keywords of all the 1558 papers were analyzed through VOSviewer. As shown in Fig. 5, the keywords were classified into 3 clusters: "diagnosis," "treatment," and "anterior decompression" (Fig. 5A). Among the "diagnosis" cluster, keywords (defined as being used more than 60 times within an article) used in the publications of spinal tuberculosis were listed as follows: disease (118 times), diagnosis (104 times), lesion (92 times), involvement (76 times), management (63 times), and abscess (63 times). For the cluster of treatment, the primary keywords were as follows: degree (84 times), fusion (76 times), kyphosis (73 times), time (69 times), correction (64 times), surgical treatment (63 times), and loss (63 times). There was only 1 keyword in the third cluster. The number of occurrences of the word "anterior decompression" was 13. The results demonstrated that the dominant fields of spinal tuberculosis were diagnosis and treatment (Supplemental Table 2, http://links.lww.com/MD/B291).

In Fig. 5, map distribution of keywords was based on the average years that they appeared within publications. The color is related to the time when the word appeared. The keywords with red color appeared early, and the one with yellow lately. The keywords were given the color by the VOSviewer. In early stage of spinal tuberculosis research, diagnosis of the spinal tuberculosis was the main hotspot. Recent trend showed that words of "lumbar spinal tuberculosis," "feasibility," and "clinical efficacy" appeared in 2013 as keywords in 16, 20, and 23 articles, respectively. "Bone fusion" appeared in 2014 as a keyword in at least 25 publications. These words all belonged to the second ("treatment") cluster. In the first ("diagnosis") cluster, "spinal deformity" and "China" appeared in 2012.5 and 2011.6. The numbers of occurrences of them were 13 and 11, respectively. There was no new word in the third ("anterior decompression") cluster in the last 5 years (Supplemental Table 2, http://links.lww.com/MD/B291).

3.7. Distribution of subjects among different countries

Diagnosis and treatment of a certain disease are key points for clinicians, so the publications for diagnosis and treatment were analyzed separately. There were 83 publications for diagnosis and 223 for treatment. L. Cormican published 2 articles on diagnosis of spinal tuberculosis. Wang Xiyang published 6 articles on treatment of the disease.[14–19] Additionally, Fudan University and Central South University in China led the research on diagnosis and treatment of spinal tuberculosis.

4. Discussion

4.1. Trend of spinal tuberculosis research

The United States and India ranked first and second for citation frequency in spinal tuberculosis research, but few publications regarding this topic have emerged in recent literature from the 2 countries. China on the other hand, has had many publications regarding spinal tuberculosis in the recent years. China ranked third in total number of articles, but fifth in citation frequency and seventh in H-index. This suggested that the quality of articles from China still required improvements. Number of citations and H-index of the United States were higher than that of any other country or region, suggesting that there were both quality and

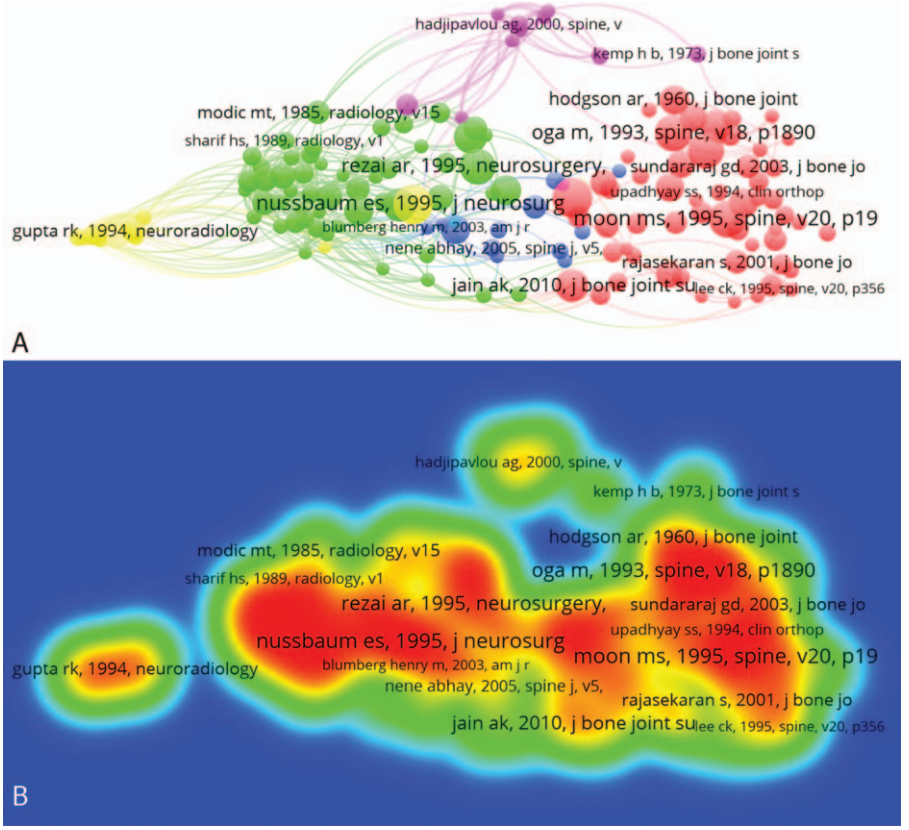

Figure 4. (A) Mapping on co-cited references of spinal tuberculosis (Note: Considering the large number of cited references, this paper selected the papers cited more than 20 times for analysis. At last, 145 papers were included in the analysis. The 145 points with different colors represent 145 cited papers. And the line between every 2 points means both were cited in one paper. If the line is thicker, the link between 2 papers is closer). (B) Mapping on density visualization of co-cited references. Different colors represent different co-cited times of papers. The color of an item was determined by the co-cited times, where by default colors range from blue (few times) to green (average times) to red (many times). Items in one red circle linked closer with each other than items in other areas. So the valuable papers with high co-cited times can be found in red circles.

quantity in their publications regarding spinal tuberculosis research.

Meanwhile, Turkey and England had fewer publications than that of China, but their citation frequency and H-index were higher than that of China. This suggested once again that more attention needs to be given to improving the quality of Chinese research.

It is of note that the journals *Spine*, *European Spine Journal*, and *International Orthopedics* were the main journals involved in publishing spinal tuberculosis research. It indicated future developments within spinal tuberculosis would likely be showcased within the aforementioned journals.

In terms of authors and publications, Jain A.K., Zhang H.Q., and Rajasekaran S. had published the most articles on spinal tuberculosis. Jain A.K. focused on neurological deficit in tuberculosis of the spine as well as its diagnosis.[20,21] Zhang H.Q.'s articles emphasized surgical treatment of spinal tuberculosis.[22,23] Rajasekaran S. looked into the medical and surgical treatment of the disease.[24,25]

According to the analysis of subjects among different countries, China published the most publications on the diagnosis and treatment of the disease. Fudan University and Central South University led the research. These 2 institutions are good partners for cooperation for someone who wants to do related research.

4.2. Researches focused on spinal tuberculosis

Two articles written by Dr. Moon M.S. were cited the most in the surgical treatment of spinal tuberculosis. The article titled "Tuberculosis of the spine: Controversies and a new challenge" was published in *Spine* back in 1997 and was subsequently cited 1138 times. The article stated that spinal tuberculosis without unsightly kyphosis and neurologic symptoms was a medical, rather than a surgical, condition. The article further suggested that surgery should be reserved for those patients who had advanced tuberculosis with unacceptable complications such as paraplegia and/or deformity.[26] The other article by Dr. Moon M.S. titled "Posterior instrumentation and anterior interbody fusion for tuberculosis kyphosis of dorsal and lumbar spines" was cited 1079 times. Posterior instrumental stabilization and anterior interbody fusion were surgical techniques that were found to stop early disease, provide early fusion, prevent progression of kyphosis, and to correct the kyphosis (Fig. 4B).[27] In the second cluster, the article titled "Modern management of spinal tuberculosis" written by Rezai A.R. was published in *Neurosurgery* back in 1995 and was cited 949 times. In this article, early operative treatment with instrumentation in selected patients, when indicated, minimized neurological deterioration and spinal deformity, allowed early ambulation, and resulted in excellent neurological outcome (Fig. 4B).[28] In the

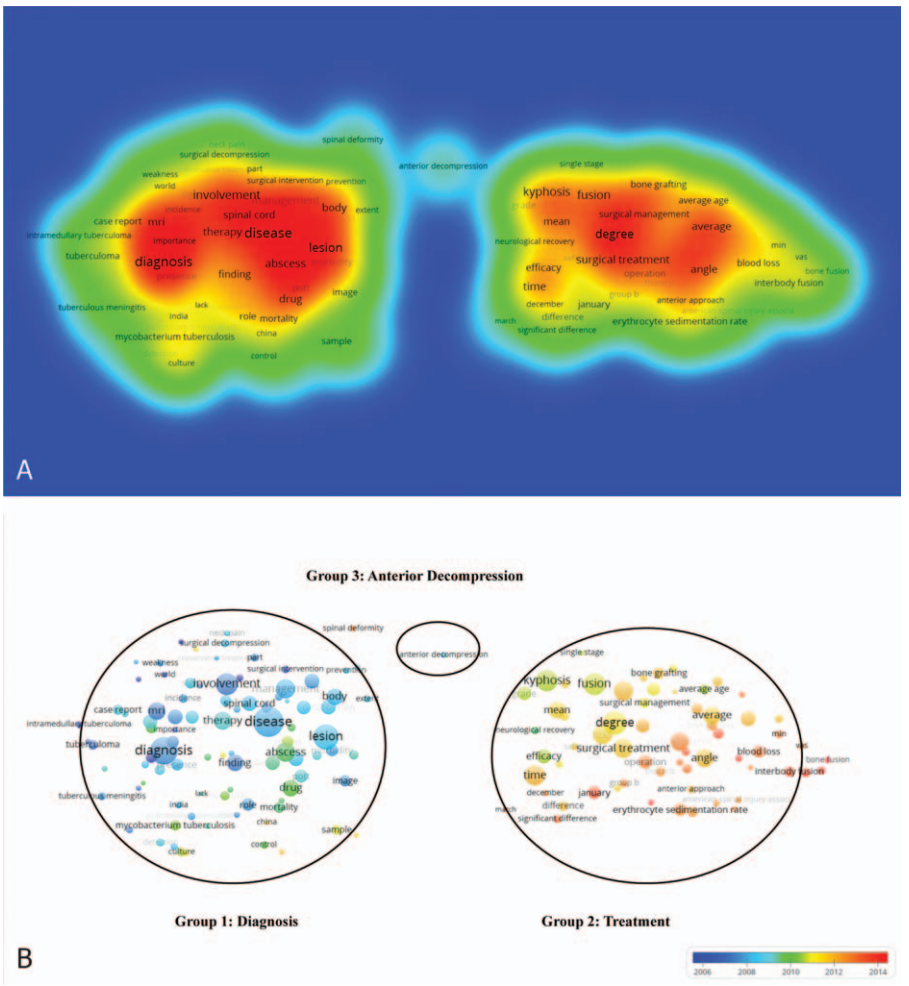

Figure 5. (A) Mapping on keywords of spinal tuberculosis. The words in central red area were used most frequently. (B) Distribution of keywords according to when they appeared for the average time. Keywords with blue color presented earlier than that with yellow. Two terms are said to co-occur if they both occur on the same line in the corpus file. In general, the smaller the distance between 2 terms, the larger the number of co-occurrences of the terms.

third cluster, Turgut M.'s article titled "Spinal tuberculosis (Pott's disease): its clinical presentation, surgical management, and outcome. A survey study on 694 patients," was published in 2001 in *Neurosurgical Review*, and was co-cited 541 times. It was concluded that the neurological involvement due to Pott's disease was relatively benign if urgent decompression was performed at the onset of the disease (Fig. 4B).[29] In the fourth cluster, Gupta R.K.'s article named "MRI in intraspinal tuberculosis" was cited 220 times and was published in *Neuroradiology* back in 1994. This article focused on the MRI features of tuberculosis meningitis and myelitis of 20 patients with intraspinal tuberculosis (Fig. 4B).[30] In the fifth cluster, an article titled "Pyogenic, tuberculosis, and brucellar vertebral osteomyelitis: a descriptive and comparative study of 219 cases" was published in *Annals of the Rheumatic Diseases* and was cited 443 times. This publication showed significant clinical, biological, radiological, and prognostic differences among pyogenic, tuberculosis, and brucellar vertebral osteomyelitis. These differences could point to the causal agent and establish the initial empirical medical treatment while awaiting a final microbiological diagnosis (Fig. 4B).[31]

Many publications were related to the diagnosis and treatment of spinal tuberculosis while a majority of researches also emphasized the surgical treatment. The bibliometric analysis showed that, bone fusion was the next hotspot in the surgical treatment of spinal tuberculosis.[32,33] The outcomes of follow-up showed that posterior and posterior–anterior surgical treatment methods were both viable surgical options for spinal tuberculosis. Interbody fusion and posterior instrumentation were feasible and effective to treat specific tubercular foci as less invasive techniques.

4.3. Strengths and limitations

Papers on spinal tuberculosis research evaluated in this study were reviewed from the Web of Science database of Science Citation Index Expanded journals. The data analysis was relatively comprehensive and objective. However, there are some limitations. Facts should be taken into consideration that the research articles from China were relatively new when compared with publications from other countries such as the United States and India. It was not long enough for the publications from China to be learned and cited. The cumulative citation rate increases as time passes by, so articles that published earlier might have more advantages. Lastly, the result of bibliometric analysis is inconsistent over time. Additionally, papers in non-English languages may be not included in the database and analyzed. Another limitation is the fact that a large portion of the literature

was not written in English. Future work should address studies in other non-English languages and adjusting for population of spinal tuberculosis patients would refine the result.

5. Conclusion

In conclusion, the bibliometric analysis showed that China had the most publications in recent years but the quality of the publications needs to be improved. *Spine* is the journal with the most publications relating to spinal tuberculosis. Jain A.K. and Rajasekaran S. had the most achievements on spinal tuberculosis research, and may be good candidates for collaborative research in this field. Bone fusion may be the latest hotspot in the spinal tuberculosis research and individuals currently involved in bone fusion research may be pioneers to lead the field in spinal tuberculosis in the next few years.

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