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Evolution of Evidence in Spine Surgery – Past, Present and Future Scientometric Analysis of Randomised Controlled Trials in Spine Surgery

Scientometric Analysis of Randomised Controlled Trials in Spine Surgery

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Abstract

BACKGROUND

Spine surgery is evolving and in the due course of its evolution, it is useful to have a comprehensive summary of the process to have a greater understanding to refine our future directives. With the multiple domains of research in the spine, it has become difficult for a surgeon to find the potential hotspots in research or identify the emerging research frontiers.

AIM

To analyze the randomized controlled trials (RCTs) published in the past three decades (1990-2019) for the potential research domains along with their research networks and identify the hot topics for future research.

METHODS

A comprehensive and systematic analysis of all the RCTs published on Spine Surgery from 1990-2019 retrieved from the Web of Science Core Collection database. Scientometric and visual analysis of their characteristics, co-operation networks, keywords, and citations were made using CiteSpace software. Journal and article impact index were retrieved from RCA Database.

RESULTS

A total of 696 RCTs were published in spine surgery from 1990-2019 of which the United States (n = 263) and China (n = 71) made a significant contribution. Thomas Jefferson University (n = 16) was the leading contributor to RCTs in spine surgery. Weinstein JN was the most cited author in the field followed by Deyo RA. Spine (n = 559) remained the top-cited journal among RCTs in spine surgery. On literature co-citation analysis, "spinal stenosis", "anterior cervical discectomy and fusion", "degenerative disc disease" and "minimally invasive decompression" were identified as the hotspots and potential research frontiers.

CONCLUSION

Research cooperation among developed and developing nations remains crucial and needs to be strengthened. It was evident from the identified hotspots that extending the frontiers in the management of degenerative disorders of the spine through further research holds the potential for advancement in spinal care.

Key Words: Randomized controlled trials; Scientometrics; Spine surgery

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Core Tip: Evolutionary process of a field is analyzed through various parameters like citation metrics, keyword and author networks in Scientometrics. With the evolution in the advancements in the field of spine, surgeons find it difficult to identify the potential hotspots for their prospective research. We identified that the research co-operation group with the closest communication was from Weinstein JN, Deyo RA, Atlas SJ, Ware JE and Fairbank JCT. We also noted the research cooperation among the developed and developing nations remains crucial and needs to be strengthened. On literature co-citation analysis, "spinal stenosis", "anterior cervical discectomy and fusion", "degenerative disc disease" and "minimally invasive decompression" were identified as the hotspots and potential research frontiers in the field of spine.

INTRODUCTION

The safety and efficacy of the evolving treatment methods in clinical practice is assessed by Randomised Controlled Trials (RCTs) which is considered as the gold standard research method being on the being on the top of the evidence pyramid.[1] With the

ongoing drive of the evidence-based approach in spine surgery, RCTs are bring used to generate clinically important findings with valid conclusions on the prognosis and diagnosis of varied clinical conditions and effectiveness of their treatment methods.[2] Hence, by analyzing the research trend of RCTs in spine surgery one could determine the evolution of evidence in the field.

With the rapid evolution in the advancements in spine surgery, in order to have a better understanding of the advancements for streamlining our future directives we need to have a comprehensive summary of the evolutionary process. Research with regards to spine has expanded to various domains and surgeons find it difficult to identify the potential hotspots in its advancement to direct their prospective research. Visualization of the evolutionary process in a field is possible with the current technological developments like information analytics, graphic drawing and data mining, combined with computational statistics. Evolutionary process of a field is analyzed through various parameters like citation metrics, keyword and author networks in Scientometrics. [3] Using knowledge maps in scientometrics one can visualize this panorama of information to explore hotspots in research.[4] This methodology has been established to study the evolution of science in fields such as educational research in fields such as orthopaedics,[5] public health,[6] and artificial intelligence[7].

With a newer perspective, scientometric tools including text mining, co-word analysis, word frequency analysis, co-citation analysis, cluster analysis, and network analysis were used to do a systematic and comprehensive review to assess the potential research domains and research trend of RCTs published on spine surgery for the past three decades (1990-2019) apart from analyzing their research networks to identify the hot topics for future research.

MATERIALS AND METHODS
Data Source

Various databases such as PubMed, Scopus, Google Scholar, Web of Science (WoS) were used by the researchers. Each has its own merits and demerits. While Google

Scholar has wider literature coverage, it is limited by the quality of results and duplication. [8] PubMed is rich in medical literature but lacks wider coverage in other subject areas.[9] Scopus and WoS were considered complementary databases without many differences. However, it was noted that for visual analysis and knowledge mapping with software such as CiteSpace, WoS was considered to be better.[9,10] Hence, the Web of Science was used as the source for data retrieval. Among the WoS databases, WoS Core Collection with indexes SCI-EXPANDED, SSCI, and A&HCI were used for data extraction. The detailed data retrieval strategy is given in Figure 1. Preliminary data was standardized with deduplication and merge functions in CiteSpace. The literature search date was 24th August 2020. The resultant core dataset on the subject is subjected to natural language processing, network analyses using CiteSpace and thematic cluster knowledge maps were developed and individual clusters are analysed using semantic network of author keywords and their hierarchy and key results are synthesized. Journal and article impact index was retrieved from RCA database.[11]

Data Visualisation and Analysis

Scientometric and visualization analysis was performed with CiteSpace (5.7.R1). CiteSpace was used to visualize the structure, regularity, and distribution of research domains in spine surgery and analyze the article co-citation data to mine the knowledge clustering and citation space distribution. The co-occurrence between the additional research units such as cooperation among various authors, institutions, and countries in the field of spine surgery was also analyzed. Consolidating the results of the analysis, a comprehensive knowledge map elaborating on the emerging research trend with the potential research domain from RCTs published in spine surgery was built.

The scientometric analysis results are depicted as knowledge maps with the key parameters detailed as follows. The knowledge map depicts the time interval between its components with warm and cold colors. With time close to 2019, the components are depicted in warm colors while time close to 1990 are depicted in cold colors. The size of the nodes in the knowledge graphs indicates the frequency of authors, institutions, and countries while the connection between them indicates that they are from the same

article.[12] When two or more authors or institutions or countries are noted in the same article, it is considered a scientific cooperative relationship between the group of authors or institutions or countries.[13]

The scientometric analysis uses certain parameters for evaluation. H-index is used to quantify the academic output from researchers and institutions where h indicates the number of papers of the author/institution having $\geq h$ citations of all the papers published by the author/institution.[14] The degree indicates the total connection between the authors, institution, or country in the analyses of their co-occurrences. A high value denotes strong co-operation and communication among the group of authors, institutions, or countries. While the importance of nodes in the research co-operation network is indicated by the Degree, the half-life represents the continuum of institutional research on a timeline.[15]

RESULTS

Database search recovered 696 RCTs published on spine surgery from the global literature 24,256 articles that included 20,458 non RCT articles, 2,206 reviews, 583 proceeding papers, and 313 meeting abstracts from 1990 to 2019. Figure 2 shows the output of the RCTs published in the field of spine surgery. The first two decades (1990-2009) had an average of 3 RCTs published per year which later increased to 51 RCTs per year in the last decade (2010-2019). There is an overall rising trend in the scientific production in spine surgery as shown in Figure 2. This rising trend of increasing publication of RCTs shows the increased attention paid in the field of spine surgery by the surgeons and researchers to improve the standard of care. It is also evident from Figure 2 that the other types of research communication documents such as original articles, reviews and proceedings papers, and meeting abstracts also had a proportionate growing trend.

Journal Analysis

The number of citations that the RCTs published in a Journal receive reflects better on the importance and influence of a journal in the field. CiteSpace was used to analyze the list of journals where the retrieved RCTs were published and generated a map of journals that cited them as depicted in Figure 3. The journal citation network had 52 nodes and 358 Links among them. Based on the citation frequency the top 10 journals were selected and tabulated in Table 1. With due consideration to the impact factor, H-index, centrality, and citation frequency of the journals, the top five journals in spine surgery are *Spine* (IF: 2.646, H-index: 243), *European Spine J* (IF: 2.458, H-index:128), *J Bone Joint Surg Am* (IF: 4.578, H-index: 322), *Spine J* (IF: 3.191, H-index: 102), *J Neurosurg-Spine* (IF: 3.011, H-index: 205). As shown in Figure 3, the node circles of *Spine, European Spine J, J Bone Joint Surg Am, Spine J, J Neurosurg-Spine* are relatively larger and there are cool-tone areas within them. However, node circles of *J Spinal Disord Tech, Neurosurgery, New Engl J Med, JAMA-J Am Med Assoc* are mostly depicted in warm colors. It denotes early critical RCTs in spine surgery were published in *Spine, European Spine J, J Bone Joint Surg Am, Spine J, J Neurosurg-Spine.* It is also worth noting that the top five journals on spine surgery came from the United States (*Spine, J Bone Joint Surg Am, Spine J, J Neurosurg-Spine)* and Germany (*European Spine J*).

Scientific Co-operation Network Analysis
Co-author Analysis

The author co-occurrence network map has 245 nodes, 1128 connections with a network density of 0.0377 as shown in Figure 4. On the whole, the authors in the network map have a fair connection strength among each other, however, as shown in Figure 4 there are some poorly connected islands of author groups that need global strengthening.

The research co-operation group with the closest communication was from Weinstein JN, Deyo RA, Atlas SJ, Ware JE, and Fairbank JCT. The details of the top 10 authors who published RCTs on spine surgery are shown in Table 2. As shown in Table 2, Weinstein James N, published the most number of RCTs in spine surgery, with a degree

value of 35 and H-index of 68. His research spans several areas in spine surgery. Weinstein JN is the principal investigator in various outcome trials involving disc herniation, spinal stenosis, and degenerative spondylolisthesis and investigated the role of surgery and conservative therapy in these conditions. He also did enormous work on pain and first developed the lumbar radiculopathy model. While Deyo Richard A (Degree: 55; H-index: 116), being a member of the Cochrane Review Group on Back Disorders conducted trials mostly on clinical intervention and patient aids for spine surgery, Atlas SJ concentrated on sciatica and spinal stenosis in spine surgery. The other two authors in the top five are Ware JE and Fairbank JCT who did pioneering works on quality of life measures in spine surgery and Oswestry Disability Index (ODI) respectively.

Co-institution Analysis

The co-institution network was presented in Figure 5 which consists of 95 nodes and 118 Links with a network density of 0.0264. As shown in Figure 5, weak collaboration exists among the institutions globally, but the network of domestic institutions seem closer than that among international institutions.

The top 10 List of institutions that published maximum RCTs were listed in Table 3. Thomas Jefferson Univ (16 RCTs), Seoul Natl Univ (11 RCTs), Univ Calif San Francisco (10 RCTs), Dartmouth Med Sch (8 RCTs), Dartmouth Inst Hlth Policy & Clin Practice (8 RCTs) were the predominant institutions with major contributions. These institutions have made a central contribution to the RCTs in Spine Surgery. It is worth noticing that 6 of the top 10 were from the United States (3 Universities, 2 Institutes, and 1 School), Sweden comes second with 2 institutions (1 University and 1 Institute) in the top 10. The contribution of United States and Sweden in the field of spine surgery has been shown to be exceptional in this analysis.

Co-country Analysis

In the co-country map depicted in Figure 6, 25 nodes and 64 Links were noted with a network density of 0.2133. From a global standpoint, the density of the network as depicted in Figure 6 is weak with few connections between the countries in terms of conducting RCTs in spine surgery. It is evident from Figure 6 that further global cooperation is needed for research in spine surgery. With the rising demand for advancement in the management of spinal ailments, countries must try to solve the problem by coordinating their efforts together for the conduction of RCTs. Table 4 shows the top 10 countries publishing RCTs in spine surgeries, it is evident that the country that has contributed to the field of spine surgery with publication of maximum RCTs is the USA, with 263 RCTs accounting for 37.8% of the global contribution.

The rest of the countries contributing to the publication of RCTs in spine surgery include the Peoples Republic of China (71 RCTs, 10.2%), Germany (59 RCTs, 8.5%), South Korea (36 RCTs, 5.2%), and Sweden (35 RCTs, 5%). It is noted from Figure 6 that the developed nation like the USA has a cold tone in their node circle while the Peoples Republic of China, as a developing country, which conducted RCTs later than the developed nations had a warm tone in their nodes. Despite having 71 RCTs published by the Peoples Republic of China, none of their authors or institutions were in the top 10 List of contributors. It indicates that despite the late start of research in the field in the country it has developed at a rapid rate to achieve the current number of published RCTs.

Keyword Analysis

We analyzed the co-occurrence network of the key words used in the field and their summary and classification based on research direction and frequency is given in Table 5. The keywords are manually sorted into five major topics. The first topic includes localizing keywords such as "spine (133)", "lumbar spine (42)" and "cervical spine (7)". It focuses mainly on the region of the spine involved in RCTs. Topic 2 includes keywords

related to disease pathology involved in RCTs such as "spondylolisthesis (11)", "disease (9)", "spinal disease (7)", degenerative spondylolisthesis (5)", *etc*. The third topic of keywords involves symptomatologies such as "low back pain (104)", "pain (36)", "radiculopathy (10)" and "sciatica (7)". The fourth topic involves keywords related to management methods such as "surgery (208)", "fusion (91)", "spine surgery (87)", "outcome (79)", "management (62)", "complication (59)", *etc*. The fifth one is concerned with the outcome measure keywords such as "efficacy (40)", "reliability (9)", "risk (6)", "safety (6)", *etc*.

Co-citation Analysis

It is a common practice for the researchers to cite the evidences from the results of RCTs in their research work as references. Scientific development is made through such mutual citations of scholarly works in the field.[16] As shown in Figure 7, the citation network of RCTs published in the 1990s looks relatively sparse while the network of RCTs published around the 2000s and 2010s look denser. It is also noted that highly cited RCTs are from the middle and late periods.

Based on Figure 7, the top 10 RCTs cited by frequency were presented in Table 6. It is to be noted that the frequency of citation of these RCTs was limited to the mutual citations between the 696 included RCTs which is different from the citation frequency available in the Web of Science. The article "Surgical *vs* Nonoperative Treatment for Lumbar Disk Herniation – The Spine Patient Outcomes Research Trial (SPORT) Observational Cohort" by Weinstein JN is the most frequently cited RCT in spine surgery. This pioneering work established the equivalence in the effectiveness of surgical and conservative treatment for lumbar disc herniation. The burst value in the table shows that these articles had been the focus of research for a period of time. The highest burst value was noted for the same article mentioned above by Weinstein JN. It is also noted from the table that JAMA-J Am Med Assoc, Spine, New Engl J Med each contributed two articles to the top 10 List. Of the top 10 articles, 3 RCTs compared surgical and

conservative treatment for lumbar disc disease, 3 RCTs evaluated the role of growth rods in early-onset scoliosis and 3 RCTs compared the results of fusion and arthroplasty for cervical disc disease.

Cluster Analysis of Co-citation Network

Using exploratory data mining techniques, analysis of the data clusters enables the identification of important topics, and their evolutionary trends. A comprehensive clustering of the RCTs published in a given theme is done in cluster analysis and an objective projection of the principle content is visualised.[17] The RCT cluster map on spine surgery is depicted in Figure 8.

As shown in Figure 8, the time needed for clustering from far to near is depicted as the color of the clusters from cold to warm. The literatures with high burst values are presented as cluster blocks with red nodes. The higher the presence of red nodes in a cluster it denotes that the clustered topic is a research frontier and hot spot in the field. We have summarized the information of the clusters in Table 7.

Considering the cluster analysis from Figure 8 and Table 7, *"spinal stenosis"*, *"anterior cervical discectomy and fusion"*, *"degenerative disc disease"* and *"minimally invasive decompression"* are the hotspots in the field of spine surgery and considered as the potential research frontiers that need further research.

Category Co-occurrence Analysis

Based on the category co-occurrence analysis one can intuitively understand the main subjects of research in the field of concern.[18] The categories used for classification were taken from the WoS core collection database. As shown in Figure 9, the highlighted circle on the nodes indicate that it has high-intermediate values of centrality. Table 8 gives the list of top 10 categories in spine surgery with high co-occurrence frequency. From Figure 9 and Table 8 it is evident that the research categories involve multiple disciplines and fields.

DISCUSSION

We noted a rising trend in the number of published literature in spine surgery based on the research outputs analyzed. We also noted an increase in the academic activities in the field of spine surgery through a proportionate increase in the number of proceeding papers and meeting abstracts. This denotes an increase in international attention for innovation in the field of spine surgery and improvisation of the existent standards of care. With the advancements in the technology we note an increase in survival period and proportionate increase in the aging population[19], which rises the concerns to increase our focus on the degenerative disorders of the spine.

Some of the landmark papers of spine surgery research were published in *J-J Am Med Assoc* and *New Engl J Med* which were in the publishing field for more than a century with a high academic reputation. They have laid a foundation for spine surgery research and paved the way for the field-specific journals which catered to the subsequent research in spine surgery. Among the specific journals recognized in the field, *Spine, Eur Spine J, J Bone Joint Surg Am, Spine J* were affiliated with various regional, national, international societies and associations and are into publication for more than 4 decades and have contributed to progress in the field of spine surgery. Most of the hotspots in spine surgery arose from RCTs published in these high-impact journals. Researchers interested in spine surgery should closely follow the high-quality trials published by these journals in real-time.

This article has explored the research co-operation in spine surgery in three perspectives namely small-author cooperation network, intermediate-institutional co-operation network, and large-national cooperation network. We noted academic cooperation mostly among the predominant institutions in a particular country and prominent authors in an institution. In the publication of RCTs the developed nations like the United States, Germany are leading the path, while developing countries like the Peoples Republic of China with relatively more publications were not from prominent institutions or authors. Hence, increased research collaboration with the developing countries will further be conducive to advancement in spine surgery.

Research Topics & Emerging Trends

The potential research topics and emerging trends have been unveiled by analyzing the keyword co-occurrences and literature co-citations in spine surgery. Keywords are one of the research data that gives an idea about the main theme of research in a particular article. With the advanced scientometric techniques such as text mining and keyword co-occurrence analysis, we can visualize the research trend in a field and identify the hotspots of research in a field.[20] From the result of such analysis, the five main research topics in spine surgery include regional localization such as cervical and lumbar; disease pathology like spondylolisthesis, stenosis, intervertebral disc, and scoliosis; surgical treatment methods like fusion surgery, decompression surgery, instrumentation surgery, and arthroplasty; outcome measures like efficacy, risks, safety and reliability of the treatment methods.

On literature co-citation analysis it was noted that "spinal stenosis", "anterior cervical discectomy and fusion", "degenerative disc disease" and "minimally invasive decompression" are the current hotspots and research frontiers. With the global aging population of more than 60 years is expected to outnumber the children younger than 5 years by 2020 [19], spinal stenosis and its fusion procedures have become one of the major research frontiers as shown in our study. With the drive for minimally invasive surgical procedures considering their lower morbidity with minimal hospitalization period[21], much of the research efforts are being directed towards making such surgical procedures safer for these aging patients and simpler for surgeons.

Spine surgery has got technological advancements in recent years in terms of intra-operative imaging, 3D navigated surgeries, materials with nanoscale architecture, and so on.[22–25] Material science research has brought about a revolution in the instrumentation options involved in spine surgery. With the development of materials with high biocompatibility, biomechanical characteristics comparable to that of the native tissue, resulted in a faster and more physiological ossification when used in fusion surgeries of the spine.[26] Hence topics such as "discogenic pain", "nerve injury", "clinical outcome",

"biologics", "XLIF" have been the important research topics directing the progress of spine surgery as identified from this study.

Our study has few limitations. The core data used for analysis was from the WoS core collection database and RCA database. Moreover, we had English language restriction to the published RCTs included in the study. We did not consider the grey literature data such as non-published conference documents, scientific reports, dissertations, scientific archives, *etc*., for analysis of the research trend. From a visual analysis perspective, all the available information was not incorporated into the knowledge map.

Authors perspective

Our analysis has unveiled the key areas of ongoing research in spine surgery to advance the management of spinal pathologies like spinal cord injury, spondylolisthesis, spinal stenosis, intervertebral disc disease, and scoliosis. Since arthroplasty is a sought-after field of research in the orthopaedic forum, spine is no exception. However, recent trails are being conducted on surgical treatment methods like fusion surgery, decompression surgery, instrumentation surgery also apart from arthroplasty. With the current abundance of evidence on novel treatment methods employing regenerative principles utilizing mesenchymal stromal cells and its derivatives to combat various inflammatory and degenerative disorders of the body, we except more upcoming trials investigating their role in spine surgery too in the future. The current research hotspots are hereby presented in the PICO format as Table 9.

CONCLUSION

Spine surgery research was extensive with multidisciplinary methods and technologies and its development needs the involvement of researchers from various fields. We recommend strengthening of research cooperation among the developed and developing nations. This study has provided an overview of research fields in spine surgery through a systematic and comprehensive scientometric analysis of published RCTs and identified the emerging trends and research hotspots. It was evident from the identified hotspots

that degenerative disorders remain the potential frontier in spine surgery that holds the promise for future advancements in the spine surgery.

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1	Ashwin Gobbur, Vijay Kumar Konkathi, Gangireddi Suresh Babu, Girinivasan Chellamuthu, Sathish Muthu, Madhan Jeyaraman. "Past, Present and Future of Arthroscopic Research: A Scientometric Analysis of Research Frontiers in Arthroscopy", Indian Journal of Orthopaedics, 2022 Crossref	184 words — 4%
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