The 100 Most-Cited Publications in Endoscopic Spine Surgery Research

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Abstract

Study Design: A bibliometric review of the literature.

Objective: Our objective was to identify and analyze the 100 most-cited publications in the field of endoscopic spine surgery (ESS).

Methods: In order to determine the top cited 100 articles, a 3-step approach was employed. First, the 100 most-cited ESS studies were identified using the key phrase “endoscopic spine surgery.” Then, 8 keywords were identified from the 100 studies of step 1 were used to conduct a second round searching in all databases of the Web of Science. Finally, when the results of the first and second steps were overlapped, duplicated studies were removed. The 100 top-cited articles were used for further analysis.

Results: The citation number of the top 100 most-cited articles ranged from 44 to 236 with a mean value of 84.4. The most productive periods were from 2001 to 2010. The majority of publications came from Spine and Neurosurgery, where Spine holds the largest number of 35 articles, followed by Neurosurgery with 13 articles. Overall, 10 countries contributed to the 100 articles, with the most productive country being the United States, followed by Germany and Korea.

Conclusion: This bibliometric study is meant to produce a list of intellectual milestones in the field of ESS. This article’s identification of the most influential articles in the field of ESS gives us a unique and comprehensive insight into the development of ESS in the past several decades.

Keywords

endoscopic spine surgery, top cited, citation analysis, bibliometric study, Web of Science

Introduction

With the aging of the global population, the number of patients with degenerative spine disorders (DSDs) specific to the elderly is on rise.1 These DSDs severely restrict spinal mobility, walking ability, and quality of life. For that reason, elderly patients with a variety of medical comorbidities pose a serious challenge to the choice of surgical methods of spinal surgeons. The conventional surgical technique for spinal pathology is open surgery. However, postoperative sequelae and long recovery time related to surgical trauma have always been the major problems in spinal surgery.2,3 Consequently, the need for minimally invasive spine surgery (MISS) is growing as the aging population is dramatically increasing and people pay more attention to quality-of-life issues.4,5 Moreover, endoscopic spine surgery (ESS) is a subset of MISS that has been evolving rapidly and continuously to help treat elderly patients to relieve pain.6,7

The advantages of ESS are widely touted to include less injury to paraspinal ligaments and muscles, less extensive epidural scar, feasibility under local anesthesia, minimal neural manipulation, less intraoperative blood loss, a lower infection

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rate, and a shorter hospital stay. Given the technical evolution of ESS, including optics design, surgical apparatus, and specific surgical approach, its clinical application has become more practical and standardized. In the past several decades, the broad spectrum of pathologies that could be treated by minimally invasive ESS has garnered increased interest from spine surgeons, other spine care providers, and their patients. ESS, which initially limited to the treatment of intradiscal therapy and soft tissue lesions, has expanded to encompass a myriad of complex surgical procedures such as skull basilar invagination, lesions in the clivus and craniovertebral junction, resection of the odontoid process, primary and recurrent intervertebral disc diseases, spinal stenosis, spondylolisthesis, radiculopathy, spinal tumors, infections, synovial cysts, dural tears, failed back surgery syndrome, and tethered cord syndrome among other surgical techniques along with reported clinical outcomes. The more recent concepts of endoscopic spine care has been promoted by Dr Anthony Yeung, who is reviewing his over 11,000 endoscopic procedures by promoting a staged concept of surgical spine care to address the pain generators early for patients deemed too young, too old, or having too many comorbidities to be recommended for traditional spine surgery. At the rate of current development, it is reasonable to predict that ESS will be an option to treat an increasing number of spine pathology.

Since the beginning of the 20th century, numerous specialists and researchers are committed to providing new insights into ESS, and a large number of articles about ESS are published annually to showed clinical application, cases report, the surgical technical note, safety and effectiveness. Very recently, a bibliometric study on full-ESS demonstrated that the number of published articles increased by 41 times between 1997 and 2017. However, the newest study focused only on full-ESS and could not fully reflect the field of ESS due to their exclusion of thoracoscopy spine surgery, and laparoscopic spine surgery, and nasoendoscopic spine surgery. And they included all the related articles regarding their quality and citation number. Given this situation, the aim of this study was to determine a ranking of the 100 highest cited articles regarding to all kinds of endoscopies for spine surgery, in order to help researchers better determine the direction of their research. Meanwhile, these articles were further analyzed for better understanding of the qualities of classical studies and highlight the significant contribution of these studies to the field of ESS.

Materials and Methods

On March 15, 2019, we sought to identify the 100 most-cited ESS research articles published between 1950 and 2019, and excluding non-English language studies. All databases of the Web of Science (Web of Science core database, KIC-Korean Journal Database, Medline, Russian Science Citation Index, and SciELO Citation Index) were used to identify eligible studies. In order to achieve a higher comprehensiveness and accurateness of the study, a 3-step approach was adopted, as shown in the flowchart in Figure 1.

The first step, all databases of the Web of Science was searched for the key phrase “endoscopic spine surgery.” The search produced 1189 results, which were then ranked in descending order of the total number of citations. In the initial 500 studies, 100 most-cited papers on ESS were identified based on titles and abstracts. In order to provide a more comprehensive study of ESS, the title and abstract of the 100 most-cited studies were systematically analyzed for possible keywords. Combined with other keywords known to be relevant to the field of ESS research, a search query group composed of 8 phrases was established and used for a second database search by topic. Finally, the 8 key phrase identified were “endoscopic spine
surgery,” “endoscopic interlaminar discectomy,” “endoscopic transforaminal discectomy,” “laparoscopic spine surgery,” “microendoscopic spine surgery,” “thoracoscopic spine surgery,” “endoscopic endonasal spine surgery,” and “endoscopic disc surgery.”

The second step, every word is delimited by an OR term, by this means further adding search results. The second search showed 2399 results, again were ranked in descending order of the total number of total citations. In the first 500 preliminary studies, 100 articles related to ESS were selected based on titles and abstracts.

In the third step, the studies of the 2 selections were overlapped, and duplicate studies were removed. The 100 most-cited ESS studies were then selected for final analysis.

To accurately identify the top 100 studies on ESS, each result was examined manually by 2 of the listed authors independently to exclude out-of-scope research articles according to the title and abstract. The exclusion criteria were (1) articles on a broad discussion of interventional surgery; (2) articles discussing the technique of percutaneous injection; (3) articles describing only MIS; (4) articles discussing da Vinci or robot-assisted spinal surgery; (5) articles citing only a broad discussion on the history or progress of ESS; and (6) Articles DISCUSSING only microendoscopic surgery. The 100 articles with the most citations were then analyzed further, and the title, authorship, geographic origin, journal of publication, year of publication, impact factor, and citation numbers were recorded.

Results

We conducted a comprehensive search process that resulted in the finalization of 100 most-cited publications related to ESS. The 100 highest cited articles on ESS were cited from 44 (article numbers 95 to 100) to 263 (top article) times, for a total of 8444 citations, with an average of 84.44 citations per article. In these publications, “Posterolateral endoscopic excision for lumbar disc herniation, surgical technique, outcome, and complications in 307 consecutive cases,” by A. T. Yeung et al, was the most-cited article. In order to show the researchers more clearly, the 100 highest cited studies according to the total number of citations can be seen in Table 1.

All the 100 most-cited articles were published between 1992 and 2015. The most productive periods were 2001 to 2005 and 2006 to 2010, with a total of 65 articles (Table 2). The oldest of these publications, “Arthroscopic microdiscectomy.” in Arthroscopy: The Journal of Arthroscopic & Related Surgery: Official Publication of the Arthroscopy Association of North America and the International Arthroscopy Association by P. Kambin et al, was published in 1992. The most recent of these articles, “Unsuccessful percutaneous endoscopic lumbar discectomy: a single-center experience of 10228 cases” was published by K. C. Choi et al.

In total, 28 different journals published the 100 most-cited publications, with the Spine contributing most studies (n = 35), followed by Neurosurgery (n = 13 articles), Journal of Neurosurgery, Journal of Neurosurgery-Spine, and European Spine Journal (each published 6 articles of this list) (Table 3).

The 100 articles originated from a total of 10 countries (Figure 2). The country with the highest number of articles was the United States (n = 49), followed by Germany (n = 19) and then Korea (n = 15), Japan (n = 6), and China (n = 5).

Overall, authors with more than two publications of the 100 most-cited articles on ESS are listed in Table 4. Among them, Dr S. Ruetten contributed the most studies (n = 9), followed by J. J. Regan, R. G. Fessler, and G. Godolias (each of them published 7 articles). Three other authors, A. T. Yeung, P. C. McAfee, and S. H. Lee published 6 articles each.

All of the 100 most-cited articles involved 5 separate endoscope designs, including spinal endoscopy, thoracoscopy, laparoscopy, arthroscopy, and nasendoscopy. The endoscopic type with the largest number of articles on the top 100 list was spinal endoscopy (n = 75), followed by thoracoscopy (n = 10), and then laparoscopy (n = 9), nasendoscopy (n = 5), and arthroscopy (n = 1) (Figure 3).

Application of minimally invasive ESS techniques in the top 100 cited articles on ESS was listed in Figure 4. The range of the spinal disease could be covered by ESS is almost anywhere of the entire spine including cranio-vertebral spine, subaxial vertebral spine, thoracic spine, thoracolumbar spine, and lumbar spine. The site with the highest number of articles on the top 100 list was lumbar spine (n = 62), whereas the site with the lowest number was thoracolumbar (n = 2).

Discussion

With the development of minimally invasive surgical techniques, as well as the advantages of modern medical imaging and computer science, significant progression in the field of ESS have been made in recent several decades. Numerous specialists and scholars engaged in research of ESS and published a large number of articles. Recently, a bibliometric study included all the publications related to full-ESS and assessed the characteristics of worldwide research productivity. However, there has never been a comprehensive analysis of the literature regarding to all kinds of endoscopies for spine surgery to identify the most influential studies in the field. The current study presents the top 100 most-cited research publications in the field of ESS by measuring the number of citations.

A number of top-cited studies in the field of spinal surgery have been reported. In 2012, Murray et al reported for the first time that the citation number of the top 100 most-cited spine articles ranged from 240 to 1695. Till 2016, Huang et al reported that the citation number of top 100 cited articles on low back pain ranged from 249 to 1638. In the same year, Rüegsegger et al found that the citation number of the 100 most influential publications in cervical spine research ranged from 173 to 879. Most recently, Badhiwala et al reported that the citation number of the top 100 most-cited articles published in spine journals ranged from 343 to 1949. The only article published so far about the top 50 cited articles about MISS was published in 2017, with the citation number up to 321.67. To
| Rank | First author       | Year | Title                                                                 | Journal                        | No. of citations | No. of citations per year |
|------|--------------------|------|----------------------------------------------------------------------|--------------------------------|------------------|--------------------------|
| 1    | A. T. Yeung        | 2002 | Posterolateral endoscopic excision for lumbar disc herniation. Surgical technique, outcome, and complications in 307 consecutive cases | Spine                          | 263              | 15.5                     |
| 2    | S. Ruetten         | 2008 | Full-endoscopic interlaminar and transforaminal lumbar discectomy versus conventional microsurgical technique | Spine                          | 227              | 20.6                     |
| 3    | P. C. McAfee       | 1995 | The incidence of complications in endoscopic anterior thoracolumbar spinal reconstructive surgery a prospective multicenter study comprising the first 100 consecutive cases | Spine                          | 219              | 9.1                      |
| 4    | H. M. Mayer        | 1993 | Percutaneous endoscopic discectomy: surgical technique and preliminary results compared to microsurgical discectomy | Journal of Neurosurgery         | 216              |                          |
| 5    | A. B. Kassam       | 2005 | The expanded endonasal approach: a full endoscopic transnasal approach and resection of the odontoid process: technical case report | Neurosurgery                    | 197              | 14.1                     |
| 6    | L. T. Khoo         | 2005 | Microendoscopic decompressive laminotomy for the treatment of lumbar stenosis | Neurosurgery                    | 175              | 10.3                     |
| 7    | R. E. Isaacs       | 2005 | Minimally invasive microendoscopy-assisted transforaminal lumbar interbody fusion with instrumentation | Journal of Neurosurgery - Spine | 158              | 11.3                     |
| 8    | S. D. Boden        | 1998 | Laparoscopic anterior spinal arthrodesis with rhBMP-2 in a titanium interbody threaded cage | Journal of Spinal Disorders & Techniques | 156              | 7.4                      |
| 9    | J. J. Regan        | 1999 | Laparoscopic fusion of the lumbar spine: minimally invasive spine surgery. A prospective multicenter study evaluating open and laparoscopic lumbar fusion | Spine                          | 150              | 7.5                      |
| 10   | B. H. Guiot        | 2002 | A minimally invasive technique for decompression of the lumbar spine | Spine                          | 140              | 8.2                      |
| 11   | D. Rosenthal       | 1994 | Removal of a protruded thoracic disc using microsurgical endoscopy. A new technique | Spine                          | 133              | 5.3                      |
| 12   | P. C. McAfee       | 1998 | Minimally invasive anterior retroperitoneal approach to the lumbar spine. Emphasis on the lateral BAK | Spine                          | 130              | 6.2                      |
| 13   | R. G. Fessler      | 2002 | Minimally invasive cervical microendoscopic foraminotomy: an initial clinical experience | Neurosurgery                    | 125              | 7.4                      |
| 14   | T. E. Adamson      | 2001 | Microendoscopic posterior cervical laminoforaminotomy for unilateral radiculopathy: results of a new technique in 100 cases | Journal of Neurosurgery - Spine | 121              | 6.7                      |
| 15   | T. J. Huang        | 2005 | Less systemic cytokine response in patients following microendoscopic versus open lumbar discectomy | Journal of Orthopaedic Research | 119              | 8.5                      |
| 16   | Y. Ahn             | 2004 | Percutaneous endoscopic lumbar discectomy for recurrent disc herniation: surgical technique, outcome, and prognostic factors of 43 consecutive cases | Spine                          | 115              | 7.7                      |
| 17   | J. F. Zucherman    | 1995 | Instrumented laparoscopic spinal fusion. Preliminary results | Spine                          | 113              | 4.7                      |
| 18   | J. J. Regan        | 1995 | A technical report on video-assisted thoracoscopy in thoracic spinal surgery. Preliminary description | Spine                          | 110              | 4.6                      |
| 19   | S. Ruetten         | 2007 | Use of newly developed instruments and endoscopes: full-endoscopic resection of lumbar disc herniations via the interlaminar and lateral transforaminal approach | Journal of Neurosurgery - Spine | 109              | 9.1                      |
| 20   | P. O. Newton       | 1997 | Anterior release and fusion in pediatric spinal deformity. A comparison of early outcome and cost of thoracoscopic and open thoracotomy approaches | Spine                          | 104              | 4.7                      |
| 21   | S. Ruetten         | 2008 | Full-endoscopic cervical posterior foraminotomy for the operation of lateral disc herniations using 5.9-mm endoscopes: a prospective, randomized, controlled study | Spine                          | 104              | 9.5                      |
| 22   | T. A. Zdeblick     | 2000 | A prospective comparison of surgical approach for anterior L4-L5 fusion: laparoscopic versus mini anterior lumbar interbody fusion | Spine                          | 104              | 5.5                      |
| 23   | L. T. Khoo         | 2002 | Minimally invasive percutaneous posterior lumbar interbody fusion | Neurosurgery                    | 102              | 6.0                      |
| 24   | B. W. Cunningham   | 1999 | Osteogenic protein versus autologous interbody arthrodesis in the sheep thoracic spine. A comparative endoscopic study using the Bagby and Kuslich interbody fusion device | Spine                          | 101              | 5.1                      |
| 25   | T. Hoogland        | 2006 | Transforaminal posterolateral endoscopic discectomy with or without the combination of a low-dose chymopapain: a prospective randomized study in 280 consecutive cases | Spine                          | 99               | 7.6                      |
| 26   | X. Wu              | 2006 |                                                                      | Spine                          | 97               | 7.5                      |
| Rank | First author | Year | Title                                                                 | Journal                        | No. of citations | No. of citations per year |
|------|--------------|------|----------------------------------------------------------------------|--------------------------------|-----------------|--------------------------|
| 27   | M. G. Kaiser | 2002 | Comparison of the mini-open versus laparoscopic approach for anterior lumbar Interbody fusion: a retrospective review | Neurosurgery                   | 95              | 5.6                      |
| 28   | S. Ruetten   | 2005 | An extreme lateral access for the surgery of lumbar disc herniations inside the spinal canal using the full-endoscopic uniporal transformaminal approach-technique and prospective results of 463 patients | Spine                          | 93              | 6.6                      |
| 29   | N. Anand     | 2002 | Video-assisted thoracosurgery for thoracic disc disease: classification and outcome study of 100 consecutive cases with a 2-year minimum follow-up period | Spine                          | 88              | 5.2                      |
| 30   | S. Ruetten   | 2009 | Recurrent lumbar disc herniation after conventional discectomy: a prospective, randomized study comparing full-endoscopic Interlaminar and transformaminal versus microsurgical revision | Journal of Spinal Disorders & Techniques | 87              | 8.7                      |
| 31   | T. Hoogland  | 2008 | Endoscopic transformaminal discectomy for recurrent lumbar disc herniation: a prospective, cohort evaluation of 262 consecutive cases | Spine                          | 86              | 7.8                      |
| 32   | D. L. Bergey | 2004 | Endoscopic lateral transposa approach to the lumbar spine             | Spine                          | 86              | 5.7                      |
| 33   | C. A. Dickman| 1996 | Thoracic vertebrectomy and reconstruction using a microsurgical thoracoscopic approach | Neurosurgery                   | 86              | 3.7                      |
| 34   | T. Moro      | 2003 | An anatomic study of the lumbar plexus with respect to retroperitoneal endoscopic surgery | Spine                          | 85              | 5.3                      |
| 35   | J. P. Wolinsky| 2007 | Endoscopic image-guided odontoidectomy for decompression of basilar invagination via a standard anterior cervical approach. Technical note | Journal of Neurosurgery - Spine | 85              | 7.1                      |
| 36   | S. Lee       | 2007 | Percutaneous endoscopic lumbar discectomy for migrated disc herniation: classification of disc migration and surgical approaches | European Spine Journal         | 84              | 7.0                      |
| 37   | K. Ikuta     | 2005 | Short-term results of microendoscopic posterior decompression for lumbar spinal stenosis. Technical note | Journal of Neurosurgery - Spine | 84              | 6.0                      |
| 38   | J. Nellensteijn| 2010 | Transforaminal percutaneous endoscopic discectomy in the treatment of far-lateral and foraminal lumbar disc herniations | European Spine Journal         | 83              | 9.2                      |
| 39   | S. M. Lew    | 2001 | Transforaminal endoscopic surgery for symptomatic lumbar disc herniations: a systematic review of the literature | Journal of Neurosurgery         | 83              | 4.6                      |
| 40   | S. H. Lee    | 2006 | Operative failure of percutaneous endoscopic lumbar discectomy: a radiologic analysis of 55 cases | Spine                          | 83              | 6.4                      |
| 41   | P. O. Newton | 2000 | Defining the pediatric spinal thoracoscopic learning curve: sixty-five consecutive cases | Spine                          | 83              | 4.4                      |
| 42   | G. Choi      | 2008 | Percutaneous endoscopic approach for highly migrated intracanal disc herniations by foraminoplasty technique using rigid working channel endoscope | Spine                          | 82              | 7.5                      |
| 43   | A. T. Yeung  | 2000 | The evolution of percutaneous spinal endoscopy and discectomy         | Mount Sinai Journal of Medicine | 82              | 4.3                      |
| 44   | H. H. Mathews| 1995 | Laparoscopic discectomy with anterior lumbar interbody fusion. A preliminary review | Spine                          | 82              | 3.4                      |
| 45   | M. Teli      | 2010 | Higher risk of dural tears and recurrent herniation with lumbar micro-endoscopic discectomy | European Spine Journal         | 81              | 9.0                      |
| 46   | J. R. de Almeida| 2009 | Defining the nasopalatine line: the limit for endonasal surgery of the spine | Laryngoscope                   | 81              | 8.1                      |
| 47   | L. M. Cavallo| 2007 | The extended endoscopic endonasal approach to the clivus and cranio-vertebral junction: anatomical study | Children Nervous System         | 78              | 6.5                      |
| 48   | J. V. Nayak  | 2007 | Experience with the expanded endonasal approach for resection of the odontoid process in rheumatoid disease | American Journal of Rhinology   | 77              | 6.4                      |
| 49   | S. Ruetten   | 2006 | A new full-endoscopic technique for the interlaminar operation of lumbar disc herniations using 6-mm endoscopes: prospective 2-year results of 331 patients | Minimally Invasive Neurosurgery | 76              | 5.8                      |
| 50   | D. Rosenthal | 1998 | Thoracoscopic microsurgical excision of herniated thoracic discs        | Journal of Neurosurgery         | 76              | 3.6                      |
| 51   | D. Rosenthal | 1996 | Anterior decompression and stabilization using a microsurgical endoscopic technique for metastatic tumors of the thoracic spine | Journal of Neurosurgery         | 76              | 3.3                      |
| Rank | First author | Year | Title                                                                                                                                                                                                 | Journal                                      | No. of citations | No. of citations per year |
|------|--------------|------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------|------------------|---------------------------|
| 52   | A. M. Nowitzke | 2005 | Assessment of the learning curve of lumbar microendoscopic discectomy                                                                                                                                  | Neurosurgery                                 | 75               | 5.4                       |
| 53   | S. Ruetten    | 2009 | Surgical treatment for lumbar lateral recess stenosis with the full-endoscopic interlaminar approach versus conventional microsurgical technique: a prospective, randomized, controlled study | Journal of Neurosurgery—Spine                | 74               | 7.4                       |
| 54   | Gun Choi      | 2006 | Percutaneous endoscopic interlaminar discectomy for intracanalicular disc herniations at L5-S1 using a rigid working channel endoscope                                                                 | Neurosurgery                                 | 69               | 5.3                       |
| 55   | Y. Ahn        | 2003 | Posterolateral percutaneous endoscopic lumbar foraminotomy for L5-S1 foraminal or lateral exit zone stenosis. Technical note                                                                              | Journal of Neurosurgery                      | 68               | 4.3                       |
| 56   | L. T. Khoo    | 2002 | Thoracoscopic-assisted treatment of thoracic and lumbar fractures: a series of 371 consecutive cases                                                                                                    | Neurosurgery                                 | 66               | 3.9                       |
| 57   | P. Kambin     | 1992 | Arthrosopic microdiscectomy                                                                                                                                                                | Spine Journal                                | 64               | 2.4                       |
| 58   | D. Y. Lee     | 2009 | Comparison of percutaneous endoscopic lumbar discectomy and open lumbar microdiscectomy for recurrent disc herniation                                                                               | Journal of Korean Neurosurgical Society      | 63               | 6.3                       |
| 59   | M. Schubert   | 2005 | Endoscopic transfominal nucleotomy with foraminoplasty for lumbar disk herniation                                                                                                                  | Operative Orthopädie und Traumatologie       | 63               | 4.5                       |
| 60   | P. M. Tsou    | 2002 | Transforaminal endoscopic decompression for radiculopathy secondary to intracanal noncontained lumbar disc herniations: outcome and technique                                                           | Spine Journal                                | 63               | 3.7                       |
| 61   | D. A. Shin    | 2008 | The efficacy of microendoscopic discectomy in reducing iatrogenic muscle injury                                                                                                                  | Journal of Neurosurgery—Spine                | 61               | 5.5                       |
| 62   | C. J. Baird   | 2009 | Radiographic and anatomic basis of endoscopic anterior craniocervical decompression: a comparison of endonasal, transoral, and transcervical approaches                                                     | Neurosurgery                                 | 61               | 6.1                       |
| 63   | U. Schick     | 2002 | Microendoscopic lumbar discectomy versus open surgery: an intraoperative EMG study                                                                                                               | European Spine Journal                        | 60               | 3.5                       |
| 64   | S. V. Roh     | 2000 | Endoscopic foraminotomy using MED system in cadaveric specimens                                                                                                                                          | Spine                                       | 60               | 3.2                       |
| 65   | P. O. Newton  | 2003 | Use of video-assisted thoracoscopic surgery to reduce perioperative morbidity in scoliosis surgery                                                                                                     | Spine                                       | 59               | 3.7                       |
| 66   | Y. Ahn        | 2013 | Radiation exposure to the surgeon during percutaneous endoscopic lumbar discectomy a prospective study                                                                                                   | Spine                                       | 58               | 9.7                       |
| 67   | B. Wang       | 2011 | An evaluation of the learning curve for a complex surgical technique: the full endoscopic interlaminar approach for lumbar disc herniations                                                           | Spine Journal                                | 58               | 7.3                       |
| 68   | S. Ruetten    | 2009 | Full-endoscopic anterior decompression versus conventional anterior decompression and fusion in cervical disc herniations                                                                             | International Orthopaedics                  | 58               | 5.8                       |
| 69   | K. T. Foley   | 1999 | Microendoscopic approach to far-lateral lumbar disc herniation                                                                                                                                     | Neurosurgical Focus                          | 58               | 2.9                       |
| 70   | J. J. Regan   | 1996 | Laparoscopic fusion of the lumbar spine in a multicenter series of the first 34 consecutive patients                                                                                                    | Surgical Laparoscopy & Endoscopy            | 57               | 2.5                       |
| 71   | G. Choi       | 2007 | Percutaneous endoscopic discectomy for extraforaminal lumbar disc herniations: extraforaminal targeted fragmentectomy technique using working channel endoscope                                               | Spine                                       | 56               | 4.7                       |
| 72   | E. J. Wall    | 2005 | Endoscopic mechanical spinal hemiepiphyseodesis modifies spine growth                                                                                                                               | Spine                                       | 56               | 4.0                       |
| 73   | J. J. Regan   | 1999 | Laparoscopic approach to L4-L5 for interbody fusion using BAK cages: experience in the first 58 cases                                                                                                  | European Spine Journal                       | 56               | 2.8                       |
| 74   | R. Sasaoka    | 2006 | Objective assessment of reduced invasiveness in MED                                                                                                                                               | Journal of Clinical Neuroscience              | 55               | 3.4                       |
| 75   | H. Nakagawa   | 2003 | Microendoscopic discectomy (MED) for lumbar disc prolapse                                                                                                                                          | Neurologia Medico-Chirurgica                 | 55               | 5.0                       |
| 76   | D. Y. Lee     | 2008 | Learning curve for percutaneous endoscopic lumbar discectomy                                                                                                                                       | Journal of Spinal Disorders & Techniques     | 54               | 4.2                       |
| 77   | J. S. Jang    | 2006 | Transforaminal percutaneous endoscopic discectomy in the treatment of foraminal and extraforaminal lumbar disc herniations                                                                         |                                             |                  |                           |

(continued)
| Rank | First author       | Year | Title                                                                 | Journal                              | No. of citations | No. of citations per year |
|------|--------------------|------|----------------------------------------------------------------------|--------------------------------------|------------------|--------------------------|
| 78   | H. H. Mathews      | 1996 | Transforaminal endoscopic microdiscectomy                            | Neurosurgery Clinics of North America | 54               | 2.3                      |
| 79   | S. H. Lee          | 2006 | Comparative radiologic evaluation of percutaneous endoscopic lumbar discectomy and open microdiscectomy: a matched cohort analysis | Mount Sinai Journal of Medicine       | 53               | 4.1                      |
| 80   | F. Asgarzade       | 2007 | Minimally invasive operative management for lumbar spinal stenosis: overview of early and long-term outcomes | Orthopedic Clinics of North America  | 52               | 4.3                      |
| 81   | D. A. Ditsworth    | 1998 | Endoscopic transforaminal lumbar discectomy and reconfiguration: a postero-lateral approach into the spinal canal | Surgical Neurology                   | 52               | 2.5                      |
| 82   | S. Ruetten         | 2007 | A new full-endoscopic technique for cervical posterior foraminotomy in the treatment of lateral disc herniations using 6.9-mm endoscopes: prospective 2-year results of 87 patients | Minimally Invasive Neurosurgery      | 50               | 4.2                      |
| 83   | J. Destandau       | 1999 | A special device for endoscopic surgery of lumbar disc herniation    | Neurological Research                 | 50               | 2.5                      |
| 84   | H.T. Hsu           | 2013 | Learning curve of full-endoscopic lumbar discectomy                  | European Spine Journal               | 49               | 8.2                      |
| 85   | B. W. Cunningham   | 1998 | Video-assisted thoracoscopic surgery versus open thoracotomy for anterior thoracic spinal fusion. A comparative radiographic, biomechanical, and histologic analysis in a sheep model | Spine                               | 49               | 2.3                      |
| 86   | J. J. Regan        | 1997 | Endoscopic techniques in spinal surgery                              | Clinical Orthopaedics and Related Research | 48               | 2.2                      |
| 87   | P. C. McAfee       | 1995 | Anterior thoracic corpectomy for spinal cord decompression performed endoscopically | Surgical Laparoscopy & Endoscopy     | 48               | 2.0                      |
| 88   | K. Muramatsu       | 2001 | Postoperative magnetic resonance imaging of lumbar disc herniation: comparison of microendoscopic discectomy and Love’s method | Spine                               | 47               | 2.6                      |
| 89   | Y. Ahn             | 2012 | Transforaminal percutaneous endoscopic lumbar discectomy: technical tips to prevent complications | Expert Review of Medical Devices     | 47               | 6.7                      |
| 90   | E. Escobar         | 2003 | Video-assisted versus open anterior lumbar spine fusion surgery: a comparison of four techniques and complications in 135 patients | Spine                               | 47               | 2.9                      |
| 91   | M. Ito             | 2007 | Clinical outcome of posterolateral endoscopic surgery for pyogenic spondylodiscitis: results of 15 patients with serious comorbid conditions | Spine                               | 46               | 3.8                      |
| 92   | P. M. Tsou         | 2004 | Posterolateral transforaminal selective endoscopic discectomy and thermal annuloplasty for chronic lumbar discogenic pain: a minimal access visualized intradiscal surgical procedure | Spine Journal                       | 46               | 3.1                      |
| 93   | K. Parikh          | 2008 | Operative results and learning curve: microscope-assisted tubular microsurgery for 1- and 2-level discectomies and laminectomies | Neurosurgical Focus                  | 45               | 4.1                      |
| 94   | A. T. Yeung        | 2003 | Advances in endoscopic disc and spine surgery: foraminal approach    | Surgical Technology International    | 45               | 2.8                      |
| 95   | T. G. Burke        | 2000 | Microendoscopic posterior cervical foraminotomy: a cadaveric model and clinical application for cervical radiculopathy | Journal of Neurosurgery              | 44               | 2.3                      |
| 96   | K. C. Choi         | 2015 | Unsuccessful percutaneous endoscopic lumbar discectomy: a single-center experience of 10,228 cases | Neurosurgery                         | 44               | 11.0                     |
| 97   | V. A. Morera       | 2010 | Far-medial expanded endonasal approach to the inferior third of the clivus: the transcondylar and transtubercular approaches | Neurosurgery                         | 44               | 4.9                      |
| 98   | H. Wang            | 2004 | Learning curve for percutaneous endoscopic lumbar discectomy depending on the surgeon’s training level of minimally invasive spine surgery | Clinical Neurology and Neurosurgery  | 44               | 2.9                      |
| 99   | G. D. Picetti III  | 2013 | Thoracoscopic techniques for the treatment of scoliosis: early results in procedure development | Neurosurgery                         | 44               | 7.3                      |
| 100  | K. M. Echholz      | 2002 | Thoracic microendoscopic discectomy                                   | Journal of Neurosurgery Spine         | 44               | 2.6                      |
the best of our knowledge, this present study is the first to identify the 100 most-cited studies focused on all kinds of ESS. However, the current 100 highest cited articles on ESS were cited 44 to 263 times. In comparison, the citation number of articles on ESS was relatively smaller than most of the previous bibliometric studies. This could be attributed to the relatively late application of endoscope in the field of spine surgery. In 1988, Dr P. Kambin et al. first proposed the concept of endoscopic lumbar discectomy. Since then, a growing number of researchers and surgeons have focused on ESS. Over the past 2 decades, although ESS has garnered increased attention from spine surgeons and their patients, due to the limited indications of ESS, the acceptance of ESS by some spine surgeons was still relatively limited. Moreover, inexperienced young spine surgeon without formal training are unable to perform ESS well due to the relatively steep and long learning curve compared with classical open surgery. Finally, as a relatively new field, less people participate in the basic research of this surgical technique. As a result, a total of 408 articles only were identified between 1997 and 2018.

There is no doubt that the publishing date can affect citation numbers, the longer the time period after the article publication, the greater chance the article could be cited. Our study showed that the most productive periods were 2001 to 2005 and 2006 to 2010, with a total of 65 articles. However, there were only 6 articles (with 300 citations in total) published from 2011 to 2015. Furthermore, the mean number of citations for the articles published from 1991 to 1995 was 123.1, while for the articles published from 2011 to 2015, the mean number of citations was 50.

### Table 2. Top 100 Most-Cited Articles on Endoscopic Spine Surgery According to Years of Publication.

| Years of publication | No. of articles | No. of total citations | Mean no. of citations |
|----------------------|-----------------|------------------------|-----------------------|
| 1991-1995            | 8               | 985                    | 123.1                 |
| 1996-2000            | 21              | 1676                   | 77                    |
| 2001-2005            | 32              | 2967                   | 92.7                  |
| 2006-2010            | 33              | 2516                   | 76.2                  |
| 2011-2015            | 6               | 300                    | 50                    |

### Table 3. Journals With More Than One Article in the 100 Most-Cited Articles on Endoscopic Spine Surgery.

| Journal title                      | No. of articles | No. of total citations | Mean no. of citations | Impact factor |
|------------------------------------|-----------------|------------------------|-----------------------|---------------|
| Spine                              | 35              | 3511                   | 100.31                | 2.792         |
| Neurosurgery                       | 13              | 1183                   | 91.00                 | 4.475         |
| Journal of Neurosurgery            | 6               | 563                    | 93.83                 | 4.318         |
| Neurosurgery-Spine                 | 6               | 736                    | 122.67                | 2.761         |
| European Spine Journal             | 6               | 413                    | 68.83                 | 2.634         |
| Spine Journal                      | 4               | 231                    | 57.75                 | 3.119         |
| Journal of Spinal Disorders & Techniques | 3         | 297                    | 99                    | 2.31          |
| Neurosurgical Focus                | 2               | 103                    | 51.5                  | 2.647         |
| Minimally Invasive Neurosurgery    | 2               | 126                    | 63                    | NA            |
| Surgical Laparoscopy & Endoscopy   | 2               | 105                    | 52.5                  | 0.986         |
| Mount Sinai Journal of Medicine    | 2               | 135                    | 67.5                  | NA            |

Abbreviation: NA, not available.

### Figure 2. The top 100 cited articles on endoscopic spine surgery based on country.

### Figure 3. Types of endoscopes used in the top 100 cited articles.
to 2015, because the recently released articles still need time to be cited widely.

In total, 28 different journals published the top 100 most-cited studies, with the Spine contributing most studies, followed by Neurosurgery, which is inconsistent with previous report. The reason why Spine was the most productive journal and highest cited journal may be related to the fact that Spine is a top journal sought after in spine surgery publications, and its articles have a high influence. A recent study showed that the top 3 journals with the highest number of articles were World Neurosurgery, Pain Physician, and Spine. The underlined reason for the difference could be their focus only on full-ESS.

Overall, 10 countries contributed to the 100 articles, and the most productive country was the United States, which was consistent to other bibliometric studies in the field of spine surgery. The reasons for this could be closely related to the country’s investment in scientific research and the efforts of researchers. In contrast, Asian countries make a relatively small contribution to the 100 most-cited articles, which indicated that there is still a large gap of scientific studies between Asian countries and Western developed countries. This could partially be attributed to non-English language studies were excluded by our study. However, a recent study showed that if all articles published for full-ESS are considered, the largest number of articles was from China, followed by South Korea and the United States. It could be due to the relative lower quantity and late start of Asian countries.

In counting the authors who contributed to the 100 top-cited articles on ESS, we counted both first and last authors. Since the first author usually contributed most and the last author usually was the senior author, counting both authors will be better for elucidation the contribution of the researchers in this field. The authors listed in Table 4 have made a significant contribution to the development of the ESS; however, it does not mean that the contributions of the authors who are not on the list is any less. Although P. Kambin has only 1 article on the list of the 100 top cited articles, he was the pioneer who proposed the concept of endoscopic lumbar discectomy in 1988 for the first time. The worldwide used triangular safe zone to highlight the contribution of responsible researchers and countries. Moreover, this bibliometric analysis also provides interesting research directions for researchers dedicated to the study of ESS in the future.

Conclusions
This bibliometric study is meant to propose a list of intellectual milestones in the field of ESS. The 100 most-cited publications in ESS were searched and analyzed, and the contribution of the authors and their origins were identified. Concepts will also continue to evolve, as new endoscopes, instrumentation, philosophies of surgical spine care, researchers, and surgeons may use the work of our predecessors to guide future ESS-related research.

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