The Top 100 Classic Papers in Lumbar Spine Surgery

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LITERATURE REVIEW

The Top 100 Classic Papers in Lumbar Spine Surgery

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Study Design. Bibliometric review of the literature.

Objective. To analyze and quantify the most frequently cited papers in lumbar spine surgery and to measure their impact on the entire lumbar spine literature.

Summary of Background Data. Lumbar spine surgery is a dynamic and complex field. Basic science and clinical research remain paramount in understanding and advancing the field. While new literature is published at increasing rates, few studies make long-lasting impacts.

Methods. The Thomson Reuters Web of Knowledge was searched for citations of all papers relevant to lumbar spine surgery. The number of citations, authorship, year of publication, journal of publication, country of publication, and institution were recorded for each paper.

Results. The most cited paper was found to be the classic paper from 1990 by Boden *et al* that described magnetic resonance imaging findings in individuals without back pain, sciatica, and neurogenic claudication showing that spinal stenosis and herniated discs can be incidentally found when scanning patients. The second most cited study similarly showed that asymptomatic patients who underwent lumbar spine magnetic resonance imaging frequently had lumbar pathology. The third most cited paper was the 2000 publication of Fairbank and Pynsent reviewing the Oswestry Disability Index, the outcome-measure questionnaire most commonly used to evaluate low back pain. The majority of the papers originate in the United States (n = 58), and most were published in *Spine* (n = 63). Most papers were published in the 1990s (n = 49), and the 3 most common topics were low back pain, biomechanics, and disc degeneration.

Conclusion. This report identifies the top 100 papers in lumbar spine surgery and acknowledges those individuals who have contributed the most to the advancement of the study of the lumbar spine and the body of knowledge used to guide evidence-based clinical decision making in lumbar spine surgery today.

Key words: top 100, classic, most cited, lumbar spine, spine surgery.

Level of Evidence: 3

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Surgery for various conditions in the lumbar spine is common. Despite its prevalence, our knowledge of the underlying pathological mechanisms remains limited and the indications for surgical treatment remain controversial in many areas. Basic science and clinical research remain paramount in the understanding and advancement of the field of lumbar spine. Although new literature is published at increasing rates, few studies make long-lasting impacts on the field. This is the first study to analyze and quantify the most frequently cited papers in lumbar spine surgery and to measure their impact on the entire lumbar spine literature.

A citation is an expression that acknowledges the relevance given by the author to the work of others on a topic of interest in which the citation appears.[1] The primary goal of a citation is to credit the author of the work that has been previously published. The greater the number of citations an author has, the more influential that author becomes in his or her particular area of expertise. Citation analysis is used to determine the relative importance of medical journals by means of the impact factor, which is determined from the ratio of the number of citations in the current year to articles published in the journal in the 2 preceding years, divided by the number of citable items published in the same 2 years.[2–4] The impact factor has emerged as a marker of the quality and rank of a journal.

The goal of this study was to identify the 100 most cited papers relevant to lumbar spinal surgery and published in spine-related journals through an extensive search of the literature using methods validated in other similar, previously published studies in other areas.[5–7] In doing so, trends, controversies, successes, and novelties that have defined lumbar spine surgery can be readily identified.

MATERIALS AND METHODS

The Thomson Reuters Web of Science, a research platform that provides bibliographic database services and ranks journals

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according to impact factor, was used to search for papers for this study. The subject of the search was "lumbar spine surgery," with a year range of 1900 to 2014. The results were organized from most cited to least cited and those with implications in lumbar spine surgery were selected for the study, whether they were published in surgical or nonsurgical journals.

The 100 articles that matched the search criteria were then further analyzed, and the title, first author, journal and year of publication, number of citations, and country and institution of origin were recorded.

RESULTS

The search yielded a total of 65,014 papers, 16,532 of which more precisely matched the search criteria. Of those, 322 were cited 100 times or more. The top 100 papers, their first author, and their corresponding number of citations are shown

TABLE 1. The Top 100 Papers in Lumbar Spine Surgery

Rank	First Author	Citations	Rank	First Author	Citations	Rank	First Author	Citations
1	Boden[8]	1035	35	Aprill[42]	267	69	Wilke[76]	221
2	Jensen[9]	971	36	Lehmann[43]	262	70	Boden[77]	220
3	Fairbank[10]	915	37	Battie[44]	261	71	Burkus[78]	218
4	Deyo[11]	598	38	Cholewicki[45]	260	72	Panjabi[79]	217
5	Hodges[12]	574	39	Deyo[46]	259	73	Weinstein[80]	216
6	Pfirrmann[13]	566	40	Osti[47]	258	74	Shirazi-Adl[81]	208
7	Modic[14]	539	41	Gatchel[48]	257	75	Kirkaldy[82]	207
8	Roland[15]	538	42	Adams[49]	256	76	Weishaupt[83]	204
9	Wilke[16]	450	43	Burke[50]	255	77	Saal[84]	202
10	Cholesicki[17]	424	44	Roy-Camille[51]	254	78	Panjabi[85]	198
11	Fritzell[18]	422	45	Faciszewski[52]	252	79	Radebold[86]	197
12	Patrick[19]	421	46	Zindrick[53]	251	80	Fairbank[87]	196
13	Thompson[20]	420	47	Brox[54]	246	81	Riew[88]	195
14	O'Sullivan[21]	404	48	Ghiselli[55]	245	82	Katz[89]	194
15	Deyo[22]	397	49	Miller[56]	242	83	Schultz[90]	193
16	Wiesel[23]	389	50	Prolo[57]	241	84	Deyo[91]	192
17	Summers[24]	386	51	Blumenthal[58]	240	85	Van Tulder[92]	191
18	Hides[25]	370	52	Rydevik[59]	239	86	Yamamoto[93]	190
19	Boden[26]	361	53	Weinstein[60]	238	87	Dunlop[94]	189
20	Marras[27]	358	54	Coste[61]	237	88	Hicks[95]	188
21	Turner[28]	349	55	Lee[62]	236	89	Atlas[96]	187
22	Esses[29]	347	56	Weinstein[63]	235	90	Brantigan[97]	186
23	Park[30]	342	57	Deyo[64]	234	91	Kirkaldy[98]	185
24	Boden[31]	340	58	Nachemson[65]	233	92	Nicoll[99]	184
25	Weinstein[32]	337	59	Freburger[66]	232	93	Abumi[100]	183
26	Belkoff[33]	326	60	Fritzell[67]	231	94	Koes[101]	182
27	Jackson[34]	299	61	Bergmark[68]	230	95	Taimela[102]	181
28	Kuslich[35]	298	62	Schimandle[69]	229	96	Stauffer[103]	180
29	Kelsey[36]	288	63	Carragee[70]	228	97	Castro[104]	179
30	Takahashi[37]	285	64	Schlegel[71]	227	98	Etebar[105]	178
31	Ray[38]	283	65	Schultz[72]	226	99	Sato[106]	177
32	Kuslich[39]	280	66	Daltroy[73]	225	100	Weinhoffer[107]	176
33	Luoma[40]	279	67	Kumar[74]	224			
34	McCormack[41]	268	68	Hirsch[75]	223			

TABLE 2. Publication Dates

Decade	No. of Papers
1940s	1
1950s	0
1960s	1
1970s	2
1980s	19
1990s	49
2000s	28

in Table 1. The top paper was cited 3315 times, the 100th paper 176 times, and the mean number of citations for the top 100 papers was 293. The papers were published between 1949 and 2010. The oldest paper was by Nicoll,[99] which was published in 1949. The most recent paper was published in 2010 by Deyo *et al*.[91] Seventy-six percent of the top 100 cited papers were published after 1980, with the 1990s producing the largest number of highly cited papers (49%) (Table 2). The top 100 papers were published in 17 journals, with the top 3 journals publishing 75% of the articles (Table 3). The top journal was *Spine* with 63 papers, followed by the *Journal of Bone and Joint Surgery American Volume* with 7 papers and the *Journal of Bone and Joint Surgery British Volume* with 5 papers. The three most popular categories published were low back pain (LBP) with 23 papers, biomechanics with 16 papers, and disc degeneration with 9 papers (Table 4). Eighty-three first authors contributed to the top 100 papers. Ten authors contributed more than once, 3 of whom were credited with 4 or more publications and only one author, Deyo *et al*, had 5 publications in the top 100 (Table 5). The top papers originated from 14 different countries, with the United States (58%) being the most prolific (Table 6). There were 61 institutions responsible for the top cited papers, with the University of Washington contributing the most papers with 6 publications in the top 100 (Table 7).

DISCUSSION

This study identifies the authors and topics that have had the most impact on the field of lumbar spine surgery during the course of the last century and the beginning of this century. Through the identification of these classic works, we gain an insight into the history, development, and current trends in lumbar spine surgery. The findings of this study identify the papers responsible for many important developments in this field.

The most cited paper in lumbar spine surgery is the classic 1990 work by Boden *et al*[8] describing magnetic resonance imaging (MRI) findings in 67 individuals without back pain, sciatica, and neurogenic claudication. This seminal study showed that common indications for surgery (*e.g.*, herniated discs, spinal stenosis) can be incidentally found when scanning patients without neurological symptoms. The study also showed that as patients aged, these incidental findings increased in frequency. The study implied correctly that to recommend surgery for a patient, there should be a clear correlation of symptoms and radiographical findings and certainly should not be based on radiographical findings alone. Indications should be clear and unambiguous prior to surgery.

Similarly, the second most referenced study was a radiographical study of degenerative disc disease findings in asymptomatic individuals. In this study by Jensen *et al*,[9] 98 asymptomatic patients underwent lumbar spine MRI, with 52% having a bulge at 1 level, 26% having a protrusion, and 1% having a disc extrusion. The paper noted an increased amount of disc bulges with aging and the relatively common finding of a Schmorl node, a herniation of nucleus pulposus through the bony and cartilaginous endplate into the vertebral body. This paper aimed to correlate LBP with disc pathology, concluding "bulges or protrusions in people with low back pain may frequently be coincidental."

The third most cited paper was the 2000 publication of Fairbank and Pynsent[10] reviewing the Oswestry Disability Index, the outcome-measure questionnaire most commonly used to evaluate LBP. The Oswestry Disability Index is a self-administered questionnaire detailing activities of daily living that takes less than 5 minutes to complete. Published originally in 1980 and since translated into many other languages, it has become an often-used tool in spine research and in evaluating standards of medical care worldwide.

The oldest paper, published in 1949, was by Nicoll,[99] which described the relationship of traumatic lumbar instability with the posterior ligament complex. This paper is

TABLE 3. Top Journals of Publication

Journal	Impact Factor*	No. of Papers
Spine	3.355	63
The Journal of Bone and Joint Surgery, American Volume	3.234	7
The Journal of Bone and Joint Surgery, British Volume	2.689	5
Journal of the American Medical Association (JAMA)	29.978	4
Clinical Orthopaedics and Related Research	2.787	4
British Medical Journal (BMJ)	17.215	3

**As of 2013.*

TABLE 4. Most Popular Topics Ranked by Numbers of Papers

Category	No. of Papers
Low back pain	23
Biomechanics	16
Disc degeneration	9
Outcome measure tool	8
Fusion	7
Imaging	5
Spinal stenosis	5
Adjacent segment disease	5
Bone morphogenetic protein	5

one of the building blocks that led to the 3-column model of Denis,[108] frequently used to determine post-traumatic lumbar spine instability. If 2 or more of the columns (anterior, middle, and posterior) are damaged, then the spine is deemed to be "unstable."

The most recent paper, published in 2010, was by Deyo *et al*,[91] which described the trends and complications of surgery for spinal stenosis in Medicare patients from 2002 to 2007. The study demonstrated the increased rate of fusion surgical procedures for spinal stenosis during the study time span and the increased morbidity rates of fusion over simple decompression. The 100th paper on the list by Weinhoffer *et al*[107] was a biomechanical study revealing that intradiscal pressures increased significantly during flexion in discs above an instrumented spinal segment. The intradiscal pressure increased as the number of levels involved in the fusion increased. Because intradiscal pressure at the segment adjacent to the fusion is associated with adjacent segment disease,[109] this study contributed to the evolving and controversial topic of predicting and evaluating adjacent segment disease.

LBP was the most popular topic in the top 100 papers, with 23 papers dedicated to it. It is highly prevalent in society and has significant impact in health care, with a cost ranging from $84 billion to $625 billion annually.[110] Of all physical and mental health conditions, it is the fourth largest productivity burden for US employers.[111] It affects up to 80% of the population. One-half of working Americans have back pain

TABLE 6. Countries of Origin

Country of Origin	No. of Papers
United States	58
United Kingdom	7
Canada	6
Sweden	6
Japan	4
Australia	4
France	3
Germany	3

symptoms every year.[112] It is the leading care of disability in Americans younger than 45 years and the second most common reason to see a doctor in the United States.[112] Effective treatment of LBP is limited by its poorly understood pathogenesis. The number of posterior fusions has increased dramatically during the past decades. In 1996, the Food and Drug Administration approved intervertebral fusion cages. At this point, the increased rate of fusion took a noticeable jump.[113] From 1998 to 2008, the number of posterior fusions per year increased 3-fold.[114,115] Three of the top 100 most cited papers revolve around the popular and controversial issue of surgical fusion *versus* conservative management for chronic LBP. The trial of Fritzell *et al*[18] (14th most cited paper) suggested an advantage of fusion over nonsurgical care for degenerative discs in 2001 and is often cited in lumbar spine surgery. However, other studies in the top 100 have not shown this advantage, including the studies by Brox *et al*[54] and Fairbank *et al*,[87] and showed no clear evidence that spinal fusion was more beneficial than intensive rehabilitation using cognitive behavior principles for chronic LBP.

Three of the authors were credited with 4 or more publications. Deyo was the most prolific of all of the authors on the top 100 list. First author on 5 publications, his name appears as a contributing author on 9 of the top 100 papers. His papers focus on outcomes, quality of life, role of physical examination, surgical indications, and morbidity surrounding surgery in the lumbar spine. Boden had 4 works in the top 100 focusing on bone morphogenetic protein, spinal fusion, imaging for patients with LBP, and operative decision making for patients

TABLE 5. Top Authors and Topics of Publication

First Author	No. of Papers	Topic
R. A. Deyo	5	Complications, low back pain, outcome measures
S. D. Boden	4	BMP, fusion, imaging
J. Weinstein	4	Outcome measures, spinal stenosis

BMP indicates bone morphogenetic protein.

TABLE 7. Top Institutions of Origin of Papers

Institution	Location	No. of Papers
University of Washington	Seattle, WA	6
Yale University	New Haven, CT	5
Emory University	Atlanta, GA	4
Dartmouth University	Hanover, NH	4
Harvard University	Cambridge, MA	3

with herniated lumbar discs. Weinstein focused on operative decision making, spinal stenosis, and trends of spinal surgery over time. Interestingly, in 2006, all 3 of the aforementioned most prolific authors contributed to 1 study, the SPORT (Spine Patient Outcomes Research Trial) study (28th most cited article). In this study that spanned 13 spine clinics in 11 states, patients with sciatica from lumbar disc herniation were divided into standard discectomy *versus* usual nonoperative care groups. The intent-to-treat analyses showed that improvements were in favor of surgery but were small and not statistically significant for the primary outcomes.

Of the top cited papers, only 4 were published before 1980. Previous studies have suggested that older papers are more likely to be cited.[116] However, this may be misleading due to the phenomenon of "obliteration by incorporation," the process whereby data from truly classic papers are cited less frequently as they are absorbed into the body of current knowledge.[111] In this study, the journal *Spine* produced the largest number of articles in the top 100 list. It must be noted that when evaluating contributions by various journals, those journals with bimonthly publications and those that have been in circulation for the longest time have more chance of being cited by other authors.

This study has several limitations. Although Thomson Reuters Web of Knowledge helped identify commonly cited lumbar spine surgery papers, it was difficult to determine the true "lead" author of each paper. For this reason, the first author was assumed to be the primary contributor to the work and this was used to create the ranking of authors according to the number of publications. Another limitation to this study is the problem of "incomplete citing," which is described as the erroneous manner in which some citations are made in an effort to convince or persuade the readership of that particular journal, instead of giving credit to those who most significantly influenced the work. Using the impact factor as a marker for quality and rank of a journal is a possible limitation of our study. The impact factor is published annually by Thomson Reuters and is broadly based on the number of citations for a given journal. It is frequently used as an indicator of the importance of a journal to its field (although it should not be used as an indicator of a specific article's significance). The strengths and weakness of the impact factor have been discussed widely in the literature. One notable weakness is the short time frame (2 yr) that is factored into its calculation, putting fields that take longer to accumulate citations at a disadvantage.[117] Another weakness is the inclusion of noncitable items in the calculation for the impact factor, including letters, book reviews, and news items.[118] Eugene Garfield, the man who created the impact factor, stated that although it "is not a perfect tool to measure the quality of articles … there is nothing better … and is, therefore, a good technique for scientific evaluation."[119] Another limitation is the subjective nature of choosing which papers are relevant to include in the top 100 list and which should be excluded because of irrelevance to lumbar spine surgery. Finally, because the key word "lumbar spine surgery" was searched, it is possible that important contributions were missed if they did not include this specific word used for the database query, constituting another weakness.

CONCLUSION

To our knowledge, this study is the first to identify the 100 most cited papers in lumbar spine surgery. It provides an insight into the development and trends within this challenging subspecialty. This paper identifies those individuals whose contributions to the ever-growing body of knowledge have provided guidance and suggestions for further investigation.

➢ Key Points

- ❑ The most cited article was found to be the classic paper from 1990 by Boden *et al* that described MRI findings in individuals without back pain, sciatica, and neurogenic claudication showing that spinal stenosis and herniated discs can be incidentally found when scanning patients.
- ❑ The second most cited study similarly showed that asymptomatic patients who underwent lumbar spine MRI frequently had lumbar pathology.
- ❑ The third most cited paper was the 2000 publication of Fairbank and Pynsent[10] reviewing the Oswestry Disability Index, the outcome-measure questionnaire most commonly used to evaluate LBP.
- ❑ The majority of the papers originate in the United States (n = 58) and most were published in *Spine* (n = 63).
- ❑ Most papers were published in the 1990s (n = 49), and the 3 most common topics were LBP, lumbar spine biomechanics, and disc degeneration.

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