

Surgical Education's 100 Most Cited Articles: A Bibliometric Analysis



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BACKGROUND: Bibliometric analysis highlights the key topics and publications, which have shaped surgical education. Here, the 100 most cited articles in the arena of surgical education were analyzed.

METHODS: Thomson Reuters Web of Science was interrogated using the keyword search terms “surgery” and (“learning” or “skills” or “competence” or “assessment” or “training” or “procedure-based assessments” or “performance” or “technical skills” or “curriculum” or “education” or “mentoring”] to identify all English language full articles, and the 100 most cited articles were analyzed by topic, journal, author, year, institution, and country of origin.

RESULTS: A total of 403,733 eligible articles were returned and the median citation number was 164 (range: 107–1018). The most cited article (by Seymour, Yale University School of Medicine, *Annals of Surgery*, 1018 citations) focused on the use of virtual reality surgical simulation training. *Annals of Surgery* published the highest number of articles and received the most citations ($n = 16$, 3715 citations). The countries with the greatest number of publications were the USA ($n = 45$), Canada ($n = 19$), and the UK ($n = 18$). The commonest topics included simulation ($n = 45$) and assessment of clinical competence ($n = 40$).

CONCLUSION: Surgical skill acquisition and assessment was the area of focus of 85% of the most cited contemporary articles, and this study provides the most cited references, serving as a guide as to what makes a citable published work in the field of surgical education. (*J Surg Ed* 73:919–929. © 2016 Association of Program Directors in Surgery. Published by Elsevier Inc. All rights reserved.)

KEY WORDS: surgery, training, education, citations, bibliometric analysis

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INTRODUCTION

The development of surgical education and published works has a long and distinguished history, originating from Galen of Pergamon (AD 131–201), a prominent Greek physician, surgeon, and philosopher in the Roman Empire, and arguably the most accomplished of all medical researchers of antiquity. His theories dominated western medical science for more than 1500 years and his anatomical reports were a mainstay of medieval physicians' university curricula, with medical students continuing to study his writings well into the 19th century.¹

The western world's most senior surgical college, in 1505, the surgeons and barbers of Edinburgh, now known as Royal College of Surgeons of Edinburgh, UK, was formally incorporated as a Craft of the Burgh,² when a seal of cause (charter of privileges) was granted by the town council of Edinburgh, conferring certain privileges and imposing certain crucial duties, the most important of these being that every master surgeon should have full knowledge of anatomy and surgical procedures; that all apprentices be literate; and that this knowledge be thoroughly tested at the apprenticeship end. All clauses remain relevant to contemporary surgical practice, and with the development of formal training programs, the development of published research works has become allied with successful training progression and more recently associated with assessment of competence progression.

The standard of published works can be rated by means of citation analysis (ranking and evaluating an article or journal related to the number of citations received), thereby establishing a citation rank list, a surrogate marker of quality, which identifies the most influential publications.³ Several reports have used citation rank analysis to identify the most influential articles in specialist fields, including trauma and orthopedic surgery,⁴ plastic surgery,⁵ general surgery,⁶ urology,⁷ and oncology.^{8,9} Yet at the time of writing, only 1 report exists regarding the most influential articles in surgical education by Wohlauer, describing the 20 most cited publications between 2002 and 2012.¹⁰

The aim of this study was to amplify the above and determine the topics and specifically the studies that had been most cited in the arena of surgical education by means of a bibliometric analysis of the 100 most cited articles over the past 100 years.

METHODS

A search of the Thompson Reuters Web of Science citation indexing database and research platform was completed using the search term “surgery” and also using the following

TABLE 1. The Top 100 Cited Articles in Surgical Education

Rank	Citations	Study	Rank	Citations	Study
1	1018	Seymour et al. ¹¹	51	163	Hyltander et al. ⁶¹
2	811	Martin et al. ¹²	52	161	Herrell and Smith ⁶²
3	517	Grantcharov ¹³	53	160	Aggarwal et al. ⁶³
4	475	Reznick and Macrae ¹⁴	54	160	Derossis et al. ⁶⁴
5	473	Reznick et al. ¹⁵	55	154	Norcini and Burch ⁶⁵
6	429	Martling et al. ¹⁶	56	151	Aggarwal et al. ⁶⁶
7	422	Edmondson et al. ¹⁷	57	151	Grantcharov et al. ⁶⁷
8	387	Issenberg et al. ¹⁸	58	150	Wishner et al. ⁶⁸
9	369	Scott et al. ¹⁹	59	149	Sroka et al. ⁶⁹
10	353	Bridges and Diamond ²⁰	60	149	Debas et al. ⁷⁰
11	351	Fried ²¹	61	149	Winckel et al. ⁷¹
12	336	Ahlering et al. ²²	62	148	Gallagher and Satava ⁷²
13	322	Derossis ²³	63	146	Matsumoto et al. ⁷³
14	312	Regehr et al. ²⁴	64	146	Rosser et al. ⁷⁴
15	310	Gallagher ²⁵	65	144	Gurusamy et al. ⁷⁵
16	263	Anastakis et al. ²⁶	66	143	Yule et al. ⁷⁶
17	259	Reznick ²⁷	67	141	Larsen et al. ⁷⁷
18	247	Moorthy et al. ²⁸	68	141	Fraser et al. ⁷⁸
19	244	Schlachta et al. ²⁹	69	140	Scott and Dunnington ⁷⁹
20	238	Peters et al. ³⁰	70	139	Hamilton et al. ⁸⁰
21	223	Schauer et al. ³¹	71	138	Okuda et al. ⁸¹
22	223	Rosser et al. ³²	72	138	Gallagher et al. ⁸²
23	220	Bennett et al. ³³	73	137	Link et al. ⁸³
24	219	Greenberg et al. ³⁴	74	136	Gallagher et al. ⁸⁴
25	219	Meyers and Bennett ³⁵	75	135	Torkington et al. ⁸⁵
26	214	Satava ³⁶	76	135	Fried et al. ⁸⁶
27	213	Cook et al. ³⁷	77	134	Andreatta et al. ⁸⁷
28	212	Cotin et al. ³⁸	78	134	Datta et al. ⁸⁸
29	208	Aggarwal et al. ³⁹	79	134	Dahl et al. ⁸⁹
30	206	Vickers et al. ⁴⁰	80	133	Older ⁹⁰
31	203	Ahlberg et al. ⁴¹	81	133	Eastridge et al. ⁹¹
32	202	Vassiliou et al. ⁴²	82	133	Gallagher et al. ⁹²
33	195	Yule et al. ⁴³	83	128	Schueneman et al. ⁹³
34	193	Rosser et al. ⁴⁴	84	122	Haluck and Krummel ⁹⁴
35	190	Sturm et al. ⁴⁵	85	122	Liem ⁹⁵
36	188	Korndorffer et al. ⁴⁶	86	122	Simons et al. ⁹⁶
37	188	Kneebone ⁴⁷	87	121	Sloan et al. ⁹⁷
38	188	Datta et al. ⁴⁸	88	120	Marescaux et al. ⁹⁸
39	188	Darzi et al. ⁴⁹	89	118	Kneebone et al. ⁹⁹
40	186	Patel et al. ⁵⁰	90	117	Basdogan et al. ¹⁰⁰
41	185	Watson et al. ⁵¹	91	116	Yule et al. ¹⁰¹
42	182	Moulton et al. ⁵²	92	115	Liu et al. ¹⁰²
43	180	Taffinder et al. ⁵³	93	114	Bell et al. ¹⁰³
44	178	Hutter et al. ⁵⁴	94	111	Marshall et al. ¹⁰⁴
45	176	Sutherland et al. ⁵⁵	95	109	Dincler et al. ¹⁰⁵
46	176	Grober et al. ⁵⁶	96	109	O'Toole et al. ¹⁰⁶
47	173	Pisano et al. ⁵⁷	97	108	Carter et al. ¹⁰⁷
48	171	Barden et al. ⁵⁸	98	108	Senagore et al. ¹⁰⁸
49	169	Faulkner et al. ⁵⁹	99	107	Gallagher and Cates ¹⁰⁹
50	165	Munz et al. ⁶⁰	100	107	Ahlberg et al. ¹¹⁰

terms (“learning” or “skills” or “competence” or “assessment” or “training” or “workplace-based assessments”) or “procedure-based assessments” or “performance” or “technical skills” or “curriculum” or “education” or “mentoring”). The returned dataset was filtered to include only English language and full articles and sorted by number of citations, a method initially developed by Paladugu et al.⁶ The 100 most cited articles were identified, and the dataset was further evaluated examining title, first and senior author, institution and department of the first author, topic, year of publication, and the country of origin. The individual and 5-year impact factors (both for the year 2013) of each journal publishing the articles were recorded.

Surgical education was defined as a discipline covering the education of medical knowledge and the acquisition of cognitive and technical skills in the domain of surgery. Exclusion criteria were articles in languages other than English, articles focused on education issues for undergraduates, and articles focused on issues not of interest to the surgical education community.

Articles accruing identical numbers of citations were ranked by dividing the number of citations by the number of years since publication to give a citation rate.

RESULTS

The Thompson Reuters Web of Science returned 403,733 full length, English language articles. Table 1 lists the 100 most cited of these articles.¹¹⁻¹¹⁰ All of the articles were published during a 27-year period (1984-2011). The most frequently cited article by Seymour et al.,¹¹ investigating the use of virtual reality in operating room performance, was published in the *Annals of Surgery* in 2002 and cited 1018 times.

The oldest article published in 1984 by Schueneman et al.⁹³ featured at number 83, cited 128 times. The most recent article was published by the Office of Education Research at Mayo Medical School in the United States of America in 2011.³⁷ It was cited 213 times, ranked at number 27, and examined the effectiveness of technology-enhanced simulation training.

TABLE 2. Journals With the Top 100 Cited Surgical Education Articles

Journal Title	Impact Factor 2015	5-Year Impact Factor	No. of Articles in the Top 100	Number of Citations
<i>Annals of Surgery</i>	8.33	8.84	16	3715
<i>American Journal of Surgery</i>	2.29	2.74	14	3132
<i>Surgical Endoscopy and Other Interventional Techniques</i>	3.26	3.33	14	2121
<i>Journal of the American College of Surgeons</i>	5.12	5.26	6	1244
<i>Archives of Surgery</i>	4.93	4.89	5	904
<i>British Journal of Surgery</i>	5.54	5.52	4	1680
<i>Journal of the American Medical Association</i>	35.29	31.03	3	707
<i>Journal of Urology</i>	4.47	4.1	3	619
<i>British Medical Journal</i>	16.3	13.511	3	576
<i>Surgery</i>	3.38	3.77	3	561
<i>Diseases of the Colon & Rectum</i>	3.75	3.69	3	475
<i>Medical Education</i>	3.2	3.69	3	449
<i>Academic Medicine</i>	2.93	3.42	2	481
<i>Urology</i>	2.18	2.2	2	347
<i>World Journal of Surgery</i>	2.64	2.84	2	254
<i>New England Journal of Medicine</i>	55.87	54.39	1	475
<i>Lancet</i>	45.22	42.72	1	429
<i>Administrative Science Quarterly</i>	4.21	6.55	1	422
<i>Visual Computer</i>	0.91	0.89	1	212
<i>Journal of the National Cancer Institute</i>	12.58	13.58	1	206
<i>Studies in health technologies and informatics</i>	Book series	Book series	1	180
<i>Management Science</i>	2.48	3.4	1	173
<i>Medical Teacher</i>	1.68	1.91	1	154
<i>Journal of Gastrointestinal Surgery</i>	2.8	2.81	1	140
<i>Mount Sinai Journal of Medicine</i>	1.62	2.14	1	138
<i>Endoscopy</i>	5.05	4.86	1	136
<i>Cinical Orthopaedics and Related Research</i>	2.77	3.37	1	134
<i>Surgeon-Journal of the Royal Colleges of Surgeons of Edinburgh and Ireland</i>	2.18	2.11	1	133
<i>IEEE Computer Graphics and Applications</i>	0.91	1.25	1	117
<i>Presence-Teleoperators and Virtual Environments</i>	0.73	1.05	1	115
<i>Journal of Trauma-Injury Infection and Critical Care</i>	2.96	2.94	1	111
<i>American Surgeon</i>	0.82	1.11	1	108

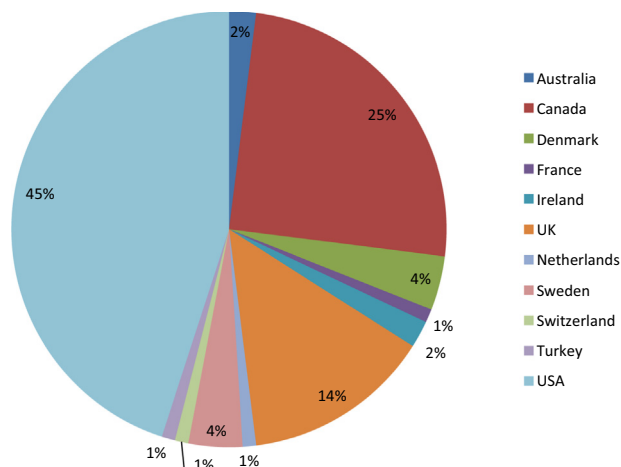


FIGURE. Proportion of citations by country.

The 100 most cited articles were across 31 journals and 1 book series with the number of articles per journal ranging from 1 to 16 (Table 2). *Annals of Surgery* published the most articles and citations ($n = 16$ and 3715 citations). The *Annals of Surgery* had an impact factor of 8.33. The *New England Journal of Medicine* had the highest impact factor (55.87), yet only 1 publication from this journal featured in the top 100 accruing 475 citations.

Most articles originated from academic institutions, and the country with the greatest number of publications was the United States of America with 45, followed by Canada with 19 publications, and the UK with 18 (Fig). The University of Toronto received the highest number of citations with 3659 and was the joint highest institution related to the number of publications in the top 100 with 12 articles (Table 3).

Some authors contributed to more than 1 article in this list. Dr. Anthony Gallagher (Emory University School of Medicine, Atlanta, GA) had the greatest number of first author publications in the top 100 ($n = 6$), and Dr. Richard Reznik (University of Toronto, Canada) had the largest volume of first author citations (1207). The senior author with the most citations was Professor Richard Satava (University of Washington, USA) with 1823.

Simulation training was the topic most widely reported ($n = 45$, Table 4), closely followed by assessment and clinical competence ($n = 40$). Reliability and validity of assessment tools and transferability of training regimens made up the focus of 15 articles, and 8 articles reported developments in clinical skills training. Most articles were research papers ($n = 76$) and reviews ($n = 16$). Of the 76 research papers, 8 were randomized controlled trials, 5 were systematic reviews, and 3 were consensus guideline statements.

A possible limitation of this type of study is that the historical article may accrue a larger number of citations despite lacking the effect of newer publications. To control for this, the number of citations were divided by the number of years since publication to give a citation rate

TABLE 3. Top 20 Institutions With the Highest Number of Articles in the Top 100

Institution	Number of Publication in Top 100	Total Number of Citations
Imperial College London	12	2062
University of Toronto	12	3659
McGill University	6	1325
Harvard University	4	923
University of Texas Southwestern medical centre	4	781
Copenhagen University	3	688
Emory university	3	550
Karolinska University Hospital	3	739
Queens University of Belfast	3	422
University of Aberdeen	3	454
Yale University	3	1387
Royal Australasian College of Surgeons	2	366
The Milton S. Hershey Medical Center	2	233
University of Miami School of Medicine, Miami	1	387
University of Tennessee Medical Center-Knoxville,	1	353
University of California (Irvine) Medical Center	1	336
The Society of American Gastrointestinal Endoscopic Surgeons	1	238
University of Pittsburgh	1	223
Chicago Healthcare System-Lakeside Division	1	220
Duke University Medical Center	1	219

(Table 5).^{11,37,14,13,12,21,25,17,69,16} The citation rate for the top 10 articles ranged from 78.3 for Seymour et al.¹¹ (virtual reality training improves operating room performance—results of a randomized, double-blinded study) to 28.6 for Martling et al.¹⁶ (effect of a surgical training program on outcome of rectal

TABLE 4. Most Frequently Referenced Topics

Subject	Number of Articles
Simulation	45
Assessment and clinical competence	40
Clinical skills	8
Communication skills	2
Professionalism	2
Cost of education	1
Patient safety	1
Teaching clinical sciences	1

TABLE 5. Top 10 Articles With the Highest Citation Rate

Rank	Citation Rate	Study	Title	Institution	Country
1	78.3	Seymour et al. ¹¹	Virtual Reality Training Improves Operating Room Performance: Results of a Randomized, Double-Blinded Study	Yale University School of Medicine	USA
2	53.2	Cook et al. ³⁷	Technology-Enhanced Simulation for Health Professions Education: A Systematic Review and Meta-analysis	Mayo Medical School	USA
3	52.7	Reznick and Macrae ¹⁴	Medical education—Teaching surgical skills—Changes in the wind	University of Toronto	Canada
4	47	Grantcharov ¹³	Randomized clinical trial of virtual reality simulation for laparoscopic skills training	University of Copenhagen & Hvidovre Hospital	Belgium
5	45	Martin et al. ¹²	Objective structured assessment of technical skill (OSATS) for surgical residents	University of Toronto	Canada
6	31.9	Fried ²¹	Proving the value of simulation in laparoscopic surgery	Steinberg-Bernstein Centre for Minimally Invasive Surgery, McGill University	Canada
7	31	Gallagher ²⁵	Virtual reality simulation for the operating room—Proficiency-based training as a paradigm shift in surgical skills training	Emory University School of Medicine	USA
8	30.1	Edmondson et al. ¹⁷	Disrupted routines: Team learning and new technology implementation in hospitals	Harvard	USA
9	29.8	Sroka et al. ⁶⁹	Fundamentals of Laparoscopic Surgery simulator training to proficiency improves laparoscopic performance in the operating room—a randomized controlled trial.	McGill University	Canada
10	28.6	Martling et al. ¹⁶	Effect of a surgical training program on outcome of rectal cancer in the County of Stockholm	Stockholm Colorectal Cancer Study Group, Karolinska Hospital	Sweden

cancer in the County of Stockholm). Canada and the USA had the most articles in the top 10 citation rate, followed by Belgium and Sweden.

DISCUSSION

Education per se, derived from the Latin word *educō* (comprising *e*; out of, and *duco*; I lead) has long been cherished as the key to improved opportunity, well-being, and quality of life. Almost 2 millennia ago, the Roman Emperor Marcus Aurelius¹¹¹ in the book “Meditations” (Book 1, AD 115-180) wrote,

“Not to have frequented public schools and to have had good teachers at home, and to realize that on such things man should spend lavishly.” Physician to the famously philosophical emperor, Claudius Galen, first sought to demonstrate the workings of the human body through dissection. His work emphasized the importance of physical practice and experimentation in the medical discipline for more than 1500 years. The principal findings of this study underpin the mantra that the surgical training and competency assessment of the here and now, equate to the patient safety and quality of care of tomorrow. Mounting pressures in the clinical environment, allied to initiatives introduced to reduce working hours and emphasis on operating room efficiency, have diminished the global surgical training time available.¹¹² Little wonder then that no fewer than 45% of the highest cited works concerned simulation skills training with the aim of better preparing trainees so that clinical operative time is optimized.¹⁴ A total of 17 of the top 100 journals were surgical, 7 were medical, 5 were technology based, and 3 were educational. Surgical journal publications attracted more citations than medical journal publications, and only 8 were randomized controlled trials, highlighting the challenges of designing such studies within educational programs.

The impact factor of a journal quantifies the average citations of the articles published within the journal during a specific period of time. Journals with a higher impact factor are recognized as being of a higher quality and therefore more likely to contain articles of importance to the scientific community. The *Annals of Surgery* with a relatively high impact factor published the most articles ranked within the top 100. Journals with very high impact factors such as the *NEJM*, the *Lancet*, and the *JAMA*, only contained 5% of the top 100 publications, and the majority were found in journals with an impact factor of 3.38 or less. The citation rate index for the surgical education articles ranked as the upper decile ranged from 78.3 to 28.6; relatively weak when compared with the citation rate index of the most influential articles published in other clinical arenas. For example, Powell et al.⁹ reported that the most influential articles related to gastric cancer had citation rates ranging from 255 to 81.

Review of the topics covered by the articles in this study revealed that the assessment of clinical competence was among the most frequently studied with 40 publications. Evaluating technical performance in surgery is challenging, and most studies have focused on techniques that standardize the assessment process. The report by Martin et al.¹⁰ had the fifth highest citation rate and compared the reliability and validity of the Objective Structured Assessment of Technical Skills, in which trainees carry out a series of standardized surgical procedures under the direct observation of an expert, to that of the more traditional Objective Structured Clinical Examination. This form of operative competence assessment has now become integral to the assessment of progression of UK surgical trainees, in the form of Procedural Based Assessments.¹¹³ Advances in technology have led to innovative developments in simulation training. Consequently, there has been a greater effort in developing virtual reality training methods, and the emergence of these studies in the top 100 confirms their relative importance to the surgical community. Moreover, virtual reality provides the opportunity for very detailed feedback and may allow for more careful assessment of performance than is possible in the clinical setting.¹¹

The main limitation of this study is the potential for several types of bias, which may confound the results. Disproportionate citation may result from institutional bias, language bias, self-citation, or powerful person bias. In addition, older journals may receive more citations, and although an attempt to control this has been made by using the citation rate index, it may take a number of years for influential articles to accrue citations because of publication lead-time.

CONCLUSION

The most cited articles highlighted in the current study describe the use of simulation training as a means of acquiring technical skills and competence, as well as reporting methods of clinical competence assessment. In addition to providing a benchmark as to what may be considered the most cited articles in surgical education, this work serves as a reference for researchers and clinicians alike as to the characteristics of a citable article in the arena of surgical education and training. The findings also suggest that newer articles have a higher citation rate that may have a significant effect on the top 100 in the next decade.

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