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TOP 50 LANDMARKS IN SENTINEL LYMPH NODE IMAGING: A BIBLIOMETRIC ANALYSIS

Y. Wu, M.K. Khan, M. Mohammed, B. Gong, F. Khosa

M.D. Student, University of British Columbia (YW), and Department of Emergency & Trauma Radiology (YW,MM,BG,FK), Vancouver General Hospital, University of British Columbia, Vancouver, BC, Canada; Department of Radiation Oncology (MKK), Emory University, Atlanta, GA, USA

ABSTRACT

Bibliometric analysis can be utilized to identify the most influential literature and track the trajectory of the research development in a given area. The purpose of this study is to summarize the top 50 most-cited landmarks and to examine the recent advances in the field of sentinel lymph node imaging. Web of Science (WOS) was searched to create a database of all English language scientific journals. This search was then cross-referenced with a similar search term query of Scopus® to identify articles that may have been missed on the initial search. Articles were ranked by citation counts and screened by two independent reviewers. Citations for the top 50 papers ranged from 2725 to 163 with a median of 240. 10 papers were cited more than 500 times. The articles were published between 1993 - 2009 across 23 journals. Our study identifies intellectual milestones in Sentinel Lymph Node Imaging (SLNI) research, reflecting on the characteristics and quality of the most highly cited literature, and provides a list of the most influential references related to SLNI.

Keywords: sentinel lymph node, cancer, imaging, bibliometrics, radioactive tracer, vital blue dye, fluorescence

Bibliometric analysis is a method to study the frequency and patterns of citations in the literature. Though it is virtually impossible to evaluate the true value of an article, citation analysis provides a simple quantitative technique to estimate the impact of an article. Citation analysis, which sorts publications by their impact, influence, and quality, is an important tool in bibliometric analyses. The two most widely-used database for bibliometrics are Thomas Reuter's Web of Science, which provides coverage of 12,000 journals, and Scopus, covering over 22,000 journals and proceeding volumes (1-3).

Most fields of medicine have published bibliometric analyses and similarly several have been published in oncology and radiology literature (4-11). However, our literature search did not reveal a bibliometric analysis of Sentinel Lymph Node Imaging (SLNI), which is the focus of our manuscript.

SLNI has emerged as the modality of choice for staging and sometimes restaging cancer (12). In the past, primary visualization techniques localizing the SLN included: 1) use of vital blue dye or isosulfan blue dye, 2) use of radioactive tracer, most commonly technetium 99m sulfur colloid, 3) combination of blue dye and radioactive tracer, and 4) fluorescence methods using indocyanine green dye (13-16). More recent developments including fusion imaging and near-infrared methods have also been introduced to visualize sentinel lymph nodes (17,18).

MATERIALS AND METHODS

A database of most-cited papers in the field of SLN biopsy was generated in June of 2016 using Thomas Reuter's Web of Science and Elsevier's Scopus, which provide access to over 12,000 and 22,000 journals, respectively. All English-language scientific journals were included regardless of country of origin, or electronic availability of article or abstract.

Key search terms included sentinel lymph node, SLN visualization techniques, and cancers. Sentinel lymph node search terms were: "sentinel lymph node," "SLN," and "sentinel node." SLN visualization techniques search terms were: "Gamma-probe," "SPY Elite," "technetium," "radiolabeled colloid," "radioactive colloid," "radiocolloid," "lymphography," "blue dye," "fluorescence," and "indocyanine green." Cancer search terms were: "cancer," "neoplasm," "tumor," "epithelioma," "carcinoma," "melanoma," "metastasis," and "metastases." The terms were combined in the following format:

(Sentinel Lymph Node OR SLN OR Sentinel Node)
AND
(Gamma-probe OR SPY Elite OR technetium OR radiolabeled colloid OR radioactive colloid OR radiocolloid OR Lymphography OR Lymphatic Mapping OR Lymphoscintigraphy OR Blue Dye OR Fluorescence OR Indocyanine Green)
AND
(Carcinoma OR Cancer OR Neoplasm OR Tumor OR Epithelioma OR Melanoma OR Metastases OR Metastasis)

The manuscripts, which met our search criteria, were reviewed for their appropriateness for inclusion by two fellowship trained and board certified radiologists and one radiation oncologist. Publications were included if they described clinical diagnostic value of SLN biopsy. Papers that focused on the long-term morbidity and mortality following SLN biopsy were excluded. Additionally, papers that did not relate to SLN biopsy, explored basic science research, or those that did not include human subjects were excluded. Meta-analyses, reviews, and case reports were also excluded.

The top 50 publications based on the above inclusion and exclusion criteria were compiled into the database. Citation counts from Scopus, Web of Science (WOS) All Database, and Web of Science (WOS) Core Collection were collected and cross-checked. Final citation counts reported below were taken from Thomas Reuter's Web of Science.

Using the method described by Lim et al (19), we collected the following: article title, WOS All Database citations, WOS Core Collection citations, Scopus citations, year, journal of publication, authors, number of authors, department affiliation, number of institutions, country of primary institution, study type, study design, sample size, imaging modality, and primary cancers identified.

Continuous variables were reported using the mean, median, and range. Categorical variables were summarized by frequency and percentage. All data were analyzed with SPSS 20 and presented below.

RESULTS

The top 50 publications are listed in *Table 1*. The publications are ranked first by total citations, then by citations per year if two articles had the same number of total citations.

Citations (Total and Citations Per Year):

The top 50 papers were cited between 163 to 2,725 times, with a median of 240 citations. On a per-year basis, the papers were cited between 7 to 109 times with a median of 16 citations per year. The top three most-cited papers, identified both by total citations and by citations per year, were: 1) "Technical details of intraoperative lymphatic mapping for early stage melanoma" with 2,725 citations and 109 citations per year, 2) "lymphatic mapping and sentinel

TABLE 1
Top 50 Most Cited Articles with Total Citations (Web of Science) and Citations Per Year, Ranked in Descending Order By Total Citations

Rank	Article Title	Total Citations (Web of Science)	Citations per year (nearest whole number)
1	Morton DL, Wen DR, Wong JH, et al. Technical details of intraoperative lymphatic mapping for early stage melanoma. Arch Surg. 1992; 127: 392-399.	2725	109
2	Giuliano AE, Kirgan DM, Guenther JM, Morton DL. Lymphatic mapping and sentinel lymphadenectomy for breast cancer. Ann Surg. 1994; 220: 391-398; discussion 398-401.	1693	74
3	Krag D, Weaver D, Ashikaga T, et al. The sentinel node in breast cancer--a multicenter validation study. N Engl J Med. 1998; 339: 941-946.	1389	73
4	Veronesi U, Paganelli G, Galimberti V, et al. Sentinel-node biopsy to avoid axillary dissection in breast cancer with clinically negative lymph-nodes. Lancet. 1997; 349: 1864-1867.	1367	68
5	Krag DN, Weaver DL, Alex JC, Fairbank JT. Surgical resection and radiolocalization of the sentinel lymph node in breast cancer using a gamma probe. Surg Oncol. 1993; 2: 335-339; discussion 340.	1021	43
6	Albertini JJ, Lyman GH, Cox C, et al. Lymphatic mapping and sentinel node biopsy in the patient with breast cancer. JAMA. 1996; 276: 1818-1822.	945	45
7	Gershenwald JE, Thompson W, Mansfield PF, et al. Multi-institutional melanoma lymphatic mapping experience: the prognostic value of sentinel lymph node status in 612 stage I or II melanoma patients. J Clin Oncol. 1999; 17: 976-983.	790	44
8	Giuliano AE, Dale PS, Turner RR, et al. Improved axillary staging of breast cancer with sentinel lymphadenectomy. Ann Surg. 1995; 222: 394-399; discussion 399-401.	642	29
9	Veronesi U, Paganelli G, Viale G, et al. Sentinel lymph node biopsy and axillary dissection in breast cancer: results in a large series. J Natl Cancer Inst. 1999; 91: 368-373.	523	29
10	Morton DL, Thompson JF, Essner R, et al. Validation of the accuracy of intraoperative lymphatic mapping and sentinel lymphadenectomy for early-stage melanoma: a multicenter trial. Multicenter Selective Lymphadenectomy Trial Group. Ann Surg. 1999; 230: 453-463; discussion 463-465.	518	29
11	Cox CE, Pendas S, Cox JM, et al. Guidelines for sentinel node biopsy and lymphatic mapping of patients with breast cancer. Ann Surg. 1998; 227: 645-651; discussion 651-653.	459	24
12	McMasters KM, Tuttle TM, Carlson DJ, et al. Sentinel lymph node biopsy for breast cancer: a suitable alternative to routine axillary dissection in multi-institutional practice when optimal technique is used. J Clin Oncol. 2000; 18: 2560-2566.	390	23
13	Albertini JJ, Cruse CW, Rapaport D, et al. Intraoperative radio-lympho-scintigraphy improves sentinel lymph node identification for patients with melanoma. Ann Surg. 1996; 223: 217-224.	387	18

Rank	Article Title	Total Citations (Web of Science)	Citations per year (nearest whole number)
14	Krag DN, Anderson SJ, Julian TB, et al. Technical outcomes of sentinel-lymph-node resection and conventional axillary-lymph-node dissection in patients with clinically node-negative breast cancer: results from the NSABP B-32 randomised phase III trial. Lancet Oncol. 2007; 8: 881-888.	382	38
15	Morton DL, Cochran AJ, Thompson JF, et al. Sentinel node biopsy for early-stage melanoma: accuracy and morbidity in MSLT-I, an international multicenter trial. Ann Surg. 2005; 242: 302-311; discussion 311-313.	366	31
16	Giuliano AE, Haigh PI, Brennan MB, et al. Prospective observational study of sentinel lymphadenectomy without further axillary dissection in patients with sentinel node-negative breast cancer. J Clin Oncol. 2000; 18: 2553-2559.	362	21
17	Gershenwald JE, Colome MI, Lee JE, et al. Patterns of recurrence following a negative sentinel lymph node biopsy in 243 patients with stage I or II melanoma. J Clin Oncol. 1998; 16: 2253-2260.	358	19
18	Krag DN, Meijer SJ, Weaver DL, et al. Minimal-access surgery for staging of malignant melanoma. Arch Surg. 1995; 130: 654-658; discussion 659-660.	350	16
19	O'Hea BJ, Hill AD, El-Shirbiny AM, et al. Sentinel lymph node biopsy in breast cancer: initial experience at Memorial Sloan-Kettering Cancer Center. J Am Coll Surg. 1998; 186: 423-427.	327	17
20	Thompson JF, McCarthy WH, Bosch CM, et al. Sentinel lymph node status as an indicator of the presence of metastatic melanoma in regional lymph nodes. Melanoma Res. 1995; 5: 255-260.	317	14
21	Hill AD, Tran KN, Akhurst T, et al. Lessons learned from 500 cases of lymphatic mapping for breast cancer. Ann Surg. 1999; 229:528-535.	285	16
22	Troyan SL, Kianzad V, Gibbs-Strauss SL, et al. The FLARE intraoperative near-infrared fluorescence imaging system: a first-in-human clinical trial in breast cancer sentinel lymph node mapping. Ann Surg Oncol. 2009; 16: 2943-2952.	283	35
23	Naik AM, Fey J, Gemignani M, et al. The risk of axillary relapse after sentinel lymph node biopsy for breast cancer is comparable with that of axillary lymph node dissection: a follow-up study of 4008 procedures. Ann Surg. 2004; 240: 462-468; discussion 468-471.	269	21
24	Wilke LG, McCall LM, Posther KE, et al. Surgical complications associated with sentinel lymph node biopsy: results from a prospective international cooperative group trial. Ann Surg Oncol. 2006; 13: 491-500.	268	24
25	Kitai T, Inomoto T, Miwa M, Shikayama T. Fluorescence navigation with indocyanine green for detecting sentinel lymph nodes in breast cancer. Breast Cancer. 2005; 12: 211-215.	243	20
26	Tafra L, Lannin DR, Swanson MS, et al. Multicenter trial of sentinel node biopsy for breast cancer using both technetium sulfur colloid and isosulfan blue dye. Ann Surg. 2001; 233: 51-59.	237	15
27	Mamounas EP, Brown A, Anderson S, et al. Sentinel node biopsy after neoadjuvant chemotherapy in breast cancer: results from National Surgical Adjuvant Breast and Bowel Project Protocol B-27. J Clin Oncol. 2005; 23: 2694-2702.	227	19

Rank	Article Title	Total Citations (Web of Science)	Citations per year (nearest whole number)
28	Morton DL, Wen DR, Foshag LJ, et al. Intraoperative lymphatic mapping and selective cervical lymphadenectomy for early-stage melanomas of the head and neck. J Clin Oncol. 1993; 11: 1751-1756.	226	9
29	Uren RF, Howman-Giles RB, Thompson JF, et al. Mammary lymphoscintigraphy in breast cancer. J Nucl Med. 1995; 36: 1775-1780.	217	10
30	Pijpers R, Meijer S, Hoekstra OS, et al. Impact of lymphoscintigraphy on sentinel node identification with technetium-99m-colloidal albumin in breast cancer. J Nucl Med. 1997; 38: 366-368.	215	11
31	Uren RF, Howman-Giles RB, Shaw HM, et al. Lymphoscintigraphy in high-risk melanoma of the trunk: predicting draining node groups, defining lymphatic channels and locating the sentinel node. J Nucl Med. 1993; 34: 1435-1440.	209	9
32	Cascinelli N, Belli F, Santinami M, et al. Sentinel lymph node biopsy in cutaneous melanoma: the WHO Melanoma Program experience. Ann Surg Oncol. 2000; 7: 469-474.	204	12
33	Klimberg VS, Rubio IT, Henry R, et al. Subareolar versus peritumoral injection for location of the sentinel lymph node. Ann Surg. 1999; 229: 860-864; discussion 864-865.	204	11
34	Klauber-DeMore N, Tan LK, Liberman L, et al. Sentinel lymph node biopsy: is it indicated in patients with high-risk ductal carcinoma-in-situ and ductal carcinoma-in-situ with microinvasion? Ann Surg Oncol. 2000; 7: 636-642.	200	12
35	de Hullu JA, Hollema H, Piers DA, et al. Sentinel lymph node procedure is highly accurate in squamous cell carcinoma of the vulva. J Clin Oncol. 2000; 18: 2811-2816.	195	11
36	Morton DL, Hoon DS, Cochran AJ, et al. Lymphatic mapping and sentinel lymphadenectomy for early-stage melanoma: therapeutic utility and implications of nodal microanatomy and molecular staging for improving the accuracy of detection of nodal micrometastases. Ann Surg. 2003; 238: 538-549; discussion 549-550.	190	14
37	Joosten JJ, Strobbe LJ, Wauters CA, et al. Intraoperative lymphatic mapping and the sentinel node concept in colorectal carcinoma. Br J Surg. 1999; 86: 482-486.	186	10
38	Levenback C, Coleman RL, Burke TW, et al. Lymphatic mapping and sentinel node identification in patients with cervix cancer undergoing radical hysterectomy and pelvic lymphadenectomy. J Clin Oncol. 2002; 20: 688-693.	185	12
39	Saha S, Wiese D, Badin J, et al. Technical details of sentinel lymph node mapping in colorectal cancer and its impact on staging. Ann Surg Oncol. 2000; 7: 120-124.	184	11
40	McMasters KM, Wong SL, Martin RC, et al. Dermal injection of radioactive colloid is superior to peritumoral injection for breast cancer sentinel lymph node biopsy: results of a multiinstitutional study. Ann Surg. 2001; 233: 676-687.	180	11
41	Kitagawa Y, Fujii H, Mukai M, et al. Radio-guided sentinel node detection for gastric cancer. Br J Surg. 2002; 89: 604-608.	178	12

Rank	Article Title	Total Citations (Web of Science)	Citations per year (nearest whole number)
42	O'Brien CJ, Uren RF, Thompson JF, et al. Prediction of potential metastatic sites in cutaneous head and neck melanoma using lymphoscintigraphy. Am J Surg. 1995; 170: 461-466.	178	8
43	Burke TW, Levenback C, Tornos C, et al. Intraabdominal lymphatic mapping to direct selective pelvic and paraaortic lymphadenectomy in women with high-risk endometrial cancer: results of a pilot study. Gynecol Oncol. 1996; 62: 169-173.	175	8
44	Nason KS, Anderson BO, Byrd DR, et al. Increased false negative sentinel node biopsy rates after preoperative chemotherapy for invasive breast carcinoma. Cancer. 2000; 89: 2187-2194.	173	10
45	Sevick-Muraca EM, Sharma R, Rasmussen JC, et al. Imaging of lymph flow in breast cancer patients after microdose administration of a near-infrared fluorophore: feasibility study. Radiology. 2008; 246: 734-741.	171	19
46	Breslin TM, Cohen L, Sahin A, et al. Sentinel lymph node biopsy is accurate after neoadjuvant chemotherapy for breast cancer. J Clin Oncol. 2000; 18: 3480-3486.	171	10
47	Linehan DC, Hill AD, Akhurst T, et al. Intradermal radiocolloid and intraparenchymal blue dye injection optimize sentinel node identification in breast cancer patients. Ann Surg Oncol. 1999; 6: 450-454.	169	9
48	Hiratsuka M, Miyashiro I, Ishikawa O, et al. Application of sentinel node biopsy to gastric cancer surgery. Surgery. 2001; 129: 335-340.	167	10
49	Guenther JM, Krishnamoorthy M, Tan LR. Sentinel lymphadenectomy for breast cancer in a community managed care setting. Cancer J Sci Am. 1997; 3: 336-340.	167	8
50	Levenback C, Burke TW, Gershenson DM, et al. Intraoperative lymphatic mapping for vulvar cancer. Obstet Gynecol. 1994; 84: 163-167.	163	7

lymphadenectomy for breast-cancer" with 1693 citations and 74 citations per year, and 3) "The sentinel node in breast cancer – a multicenter validation study" with 1,389 citations and 73 citations per year.

Year of Publication:

The year of publication of top 50 most cited papers ranged from 1992-2009. *Fig. 1* shows a graphical distribution of top-cited papers.

Number of Authors:

Authors per article ranged from 3-17, and each article had 10 authors on average.

Top authors in the field along with their institutional affiliation are summarized in *Table 2.*

Country of Origin:

United States of America is the most productive country in SLN imaging, contributing 38 manuscripts.

Journals of Publication:

The 50 most-cited articles were published in 22 different journals. *Table 3* shows the journals with two or more publications.

Additional Descriptors:

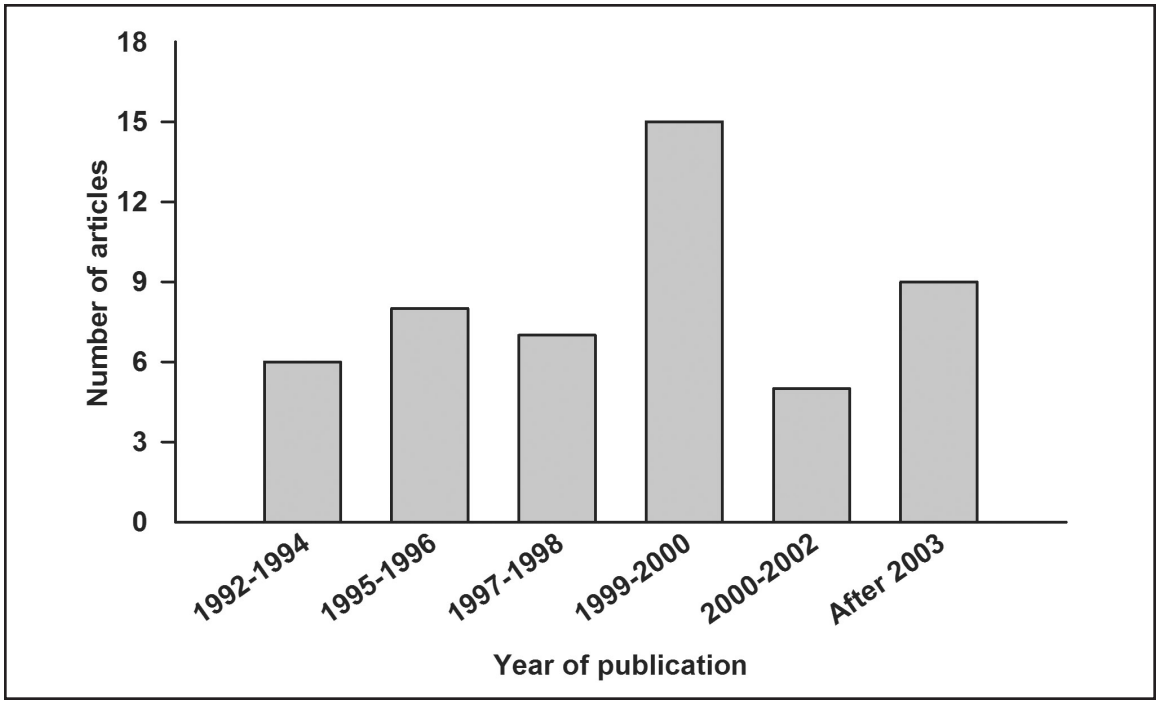

Fig. 1. Distribution of the top 50 most-cited articles in sentinel lymph node imaging by year of publication.

TABLE 2
Top Authors and Their Institution of Affiliation in the Field of Sentinel Lymph Node Imaging

Top Authors	Number of Publications (total)	First Author	Last Author	Other Authors	Institution of Affiliation
Reintgen, DS	8	0	3	5	Cutaneous Oncology, Moffitt Cancer Center and Research Institute, Tampa, FL, USA
Thompson, JF	6	1	0	5	Sydney Melanoma Unit, Sydney, Australia;
Morton, DL	7	5	1	1	John Wayne Cancer Institute, Santa Monica, CA, USA
Borgen, PI	5	0	0	5	Breast Service, Department of Surgery, Memorial Sloan-Kettering Cancer Center, New York, NY, USA.
Cody, HS	5	0	4	1	Departments of Surgery, Memorial Sloan-Kettering Cancer Center, New York City, NY, USA
Ross, MI	5	1	2	2	University of Texas M.D. Anderson Cancer Center, Houston, TX, USA
Weaver, DL	5	0	0	5	Department of Pathology, University of Vermont, Burlington, VT, USA

TABLE 3
Top Journals in Sentinel Lymph Node Imaging and Their Impact Factors

Journal of Publication (only 2+ articles)	Number of Publication	Current Impact Factor
ANNALS OF SURGERY	12	8.327
JOURNAL OF CLINICAL ONCOLOGY	9	18.428
ANNALS OF SURGICAL ONCOLOGY	6	3.93
JOURNAL OF NUCLEAR MEDICINE	3	6.16
BRITISH JOURNAL OF SURGERY	2	5.542
ARCHIVES OF SURGERY	2	2.191

We also analyzed the manuscripts based on their study designs, number of affiliated institutions, departmental affiliation of the first author, journals by specialty, sample sizes, type of cancer, and visualization techniques. This information is summarized in *Table 4*.

Literature from 2010-Present:

One limitation of performing a citation-based bibliometric analysis is that recent articles may not have accumulated enough citations to be captured. In our original analysis, only articles published up to 2009 were included due to this reason. To analyze the landmarks in recent literature, we performed another search using the same methods but restricting publication year to 2010 and onwards. The top 20 most-cited articles in this search are listed in *Table 5*, and their characteristics are summarized in *Table 6*.

DISCUSSION

In our study, we identified the top 50 landmark publications in SLNI. The top cited article, by Morton et al, is "technical details of intraoperative lymphatic mapping for early stage melanoma," published in *Archives of Surgery* in 1992. This was the first paper that described the clinical utility of SLN biopsy, in which the authors visualized lymphatic basins using vital blue dye and examined the histochemical features of biopsied nodes in clinical stage I melanoma patients (20). The second most cited article, by Giuliano et al, is "lymphatic mapping and sentinel lymphadenectomy for breast cancer," published in *Annals of Surgery*, which utilized isofuran blue dye to compare the diagnostic accuracy of SLN biopsy to conventional axillary lymph node dissection (15). The third most-cited article is "sentinel node in breast cancer – multicenter validation study" by Krag et al and published in *New England Journal of Medicine*. This article described the diagnostic parameters associated with SLN biopsy using technetium 99-m sulfur colloid (21). The three articles were also top three most cited articles on a per year basis. All three articles were published in the 1990s, when SLN biopsy began to replace lymph node dissection as the first-line modality for diagnosing nodal metastasis in early cancers.

Most of the top-cited articles were published between 1992 and 2000. This indicates the most prolific period for SLN biopsy was the 1990s, when the procedure was first described and utilized in the clinical settings. *Annals of Surgery* (n=12), *Journal of Clinical Oncology* (n=9), *Annals of Surgical Oncology* (n=6) were the top three journals that published the highest counts of most-cited articles. Most of the articles were published in oncology (n=16), surgical oncology (n=7), or surgery (n=19) related journals. Three articles were published in general medical journals, and four were published in radiology-related journals. One article was published in

TABLE 4
Study Design, Sample Size, Number of Affiliated Institutions, Visualization Techniques, and Identified Pathologies in Top 50 Most-cited Articles in Sentinel Lymph Node Imaging

	Descriptors	Number of Publications (%)
Study Design	Prospective	43 (86%)
	Retrospective	7 (14%)
Sample Size	0-49	9 (18%)
	50-99	14 (28%)
	100-199	6 (12%)
	200-299	4 (8%)
	300-399	3 (6%)
	400-499	3 (6%)
	500-999	4 (8%)
	1000+	7 (14%)
Number of Affiliated Institutions	One	8 (16%)
	Two	10 (20%)
	Three	7 (14%)
	Four	9 (18%)
	5 to 9	11 (22%)
	10+	5 (10%)
Journals by Specialty	Surgery	19 (38%)
	Oncology	16 (32%)
	Surgical Oncology	7 (14%)
	Radiology	3 (6%)
	Other	1 (2%)
Visualization Techniques	Blue Dye Only	10 (20%)
	Combination of Blue Dye and Radioactive Tracer	11 (22%)
	Two modalities	11 (22%)
	Three modalities	1 (2%)
	Radioactive tracer	13 (26%)
	Fluorescence	4 (8%)
Identified Pathologies	Breast Cancer	28 (56%)
	Melanoma	14 (28%)
	Cervical, Endometrial, and Vuvular Cancer	4 (8%)
	Gastric and Colorectal Cancer	4 (8%)

Obstetrics and Gynecology. This indicates that SLN imaging involves cross-specialty collaboration from surgery, surgical oncology, oncology, and radiology. Each publication had an average of ten authors and was affiliated with an average of four institutions, which indicates the highly collaborative nature of research in the field. United States of America (n=38) remains the most productive country followed by Australia (n=4), Netherlands (n=3), Japan (n=3), and Italy (n=2).

TABLE 5
Top 20 most Cited Articles from 2010-present with Total Citations (Web of Science) and Citations per year, Ranked in Descending Order by Total Citations

Rank	Article Title	Total Citations (Web of Science)	Citations per year (nearest whole number)
1	Boughey JC, Suman VJ, Mittendorf EA, et al. Sentinel lymph node surgery after neoadjuvant chemotherapy in patients with node-positive breast cancer: the ACOSOG Z1071 clinical trial. JAMA. 2013;310:1455-1461.	142	36
2	van der Poel HG, Buckle T, Brouwer OR, et al. Intraoperative laparoscopic fluorescence guidance to the sentinel lymph node in prostate cancer patients: clinical proof of concept of an integrated functional imaging approach using a multimodal tracer. Eur Urol. 2011; 60: 826-833.	122	20
3	Ballester M, Dubernard G, Lecuru F, et al. Detection rate and diagnostic accuracy of sentinel-node biopsy in early stage endometrial cancer: a prospective multicentre study (SENTI-ENDO). Lancet Oncol. 2011; 12: 469-476.	115	19
4	Alkureishi LW, Ross GL, Shoaib T, et al. Sentinel node biopsy in head and neck squamous cell cancer: 5-year follow-up of a European multicenter trial. Ann Surg Oncol. 2010; 17: 2459-2464.	90	13
5	Hirche C, Murawa D, Mohr Z, et al. ICG fluorescence-guided sentinel node biopsy for axillary nodal staging in breast cancer. Breast Cancer Res Treat. 2010; 121: 373-378.	82	12
6	Lecuru F, Mathevet P, Querleu D, et al. Bilateral negative sentinel nodes accurately predict absence of lymph node metastasis in early cervical cancer: results of the SENTICOL study. J Clin Oncol. 2011; 29: 1686-1691.	72	12
7	Hojo T, Nagao T, Kikuyama M, et al. Evaluation of sentinel node biopsy by combined fluorescent and dye method and lymph flow for breast cancer. Breast. 2010; 19: 210-213.	68	10
8	Crane LM, Themelis G, Arts HJ, et al. Intraoperative near-infrared fluorescence imaging for sentinel lymph node detection in vulvar cancer: first clinical results. Gynecol Oncol. 2011; 120: 291-295.	66	11
9	Levenback CF, Ali S, Coleman RL, et al. Lymphatic mapping and sentinel lymph node biopsy in women with squamous cell carcinoma of the vulva: a gynecologic oncology group study. J Clin Oncol. 2012;30:3786-3791	63	13
10	Wendler T, Herrmann K, Schnelzer A, et al. First demonstration of 3-D lymphatic mapping in breast cancer using freehand SPECT. Eur J Nucl Med Mol Imaging. 2010; 37: 1452-1461.	62	9
11	Brouwer OR, Buckle T, Vermeeren L, et al. Comparing the hybrid fluorescent-radioactive tracer indocyanine green-99mTc-nanocolloid with 99mTc-nanocolloid for sentinel node identification: a validation study using lymphoscintigraphy and SPECT/CT. J Nucl Med. 2012; 53: 1034-1040.	59	12

12	Rossi EC, Ivanova A, Boggess JF. Robotically assisted fluorescence-guided lymph node mapping with ICG for gynecologic malignancies: a feasibility study. Gynecol Oncol. 2012; 124: 78-82.	58	12
13	Vermeeren L, Valdes Olmos RA, Klop WM, et al. A portable gamma-camera for intraoperative detection of sentinel nodes in the head and neck region. J Nucl Med. 2010; 51: 700-703.	58	8
14	Joniau S, Van den Bergh L, Lerut E, et al. Mapping of pelvic lymph node metastases in prostate cancer. Eur Urol. 2013; 63: 450-458.	55	14
15	Khoury-Collado F, Murray MP, Hensley ML, et al. Sentinel lymph node mapping for endometrial cancer improves the detection of metastatic disease to regional lymph nodes. Gynecol Oncol. 2011; 122: 251-254.	55	9
16	Roth B, Wissmeyer MP, Zehnder P, et al. A new multimodality technique accurately maps the primary lymphatic landing sites of the bladder. Eur Urol. 2010; 57: 205-211.	55	8
17	Holloway RW, Bravo RA, Rakowski JA, et al. Detection of sentinel lymph nodes in patients with endometrial cancer undergoing robotic-assisted staging: a comparison of colorimetric and fluorescence imaging. Gynecol Oncol. 2012; 126: 25-29.	52	10
18	Hutteman M, Mieog JS, van der Vorst JR, et al. Randomized, double-blind comparison of indocyanine green with or without albumin premixing for near-infrared fluorescence imaging of sentinel lymph nodes in breast cancer patients. Breast Cancer Res Treat. 2011; 127: 163-170.	47	8
19	van den Berg NS, Brouwer OR, Klop WM, et al. Concomitant radio- and fluorescence-guided sentinel lymph node biopsy in squamous cell carcinoma of the oral cavity using ICG-(99m)Tc-nanocolloid. Eur J Nucl Med Mol Imaging. 2012; 39: 1128-1136.	46	9
20	Jewell EL, Huang JJ, Abu-Rustum NR, et al. Detection of sentinel lymph nodes in minimally invasive surgery using indocyanine green and near-infrared fluorescence imaging for uterine and cervical malignancies. Gynecol Oncol. 2014; 133: 274-277.	45	15

TABLE 6
Country of Origin, Journal of Publication, Study Design, Sample Size, Number of Affiliated Institutions, Visualization Techniques, and Identified Pathologies Top 20 Most-cited Articles in Sentinel Lymph Node Imaging from 2010-Present

	Descriptors	Number of Publications (%)
Country of Origin (only those with 2+ publications)	Netherlands	7 (35%)
	USA	6 (30%)
	Germany	2 (10%)
	France	2 (10%)
Journal of Publication (only those with 2+ publications)	GYNECOLOGICAL ONCOLOGY	5 (25%)
	BREAST CANCER RESEARCH AND TREATMENT	2 (10%)
	JOURNAL OF CLINICAL ONCOLOGY	2 (10%)
	JOURNAL OF NUCLEAR MEDICINE	2 (10%)
	EUROPEAN JOURNAL OF NUCLEAR MEDICINE AND MOLECULAR IMAGING	2 (10%)
	EUROPEAN UROLOGY	2 (10%)
Study Design	Prospective	18 (90%)
	Retrospective	2 (10%)
Sample Size	0-49	10 (50%)
	50-99	2 (10%)
	100-199	4 (20%)
	200-299	2 (10%)
	300 +	2 (10%)
Number of Affiliated Institutions	One	3 (15%)
	Two	3 (15%)
	Three	2 (10%)
	Four	3 (15%)
	5 to 9	5 (25%)
	10+	4 (20%)
Journals by Specialty	Oncology	11 (55%)
	Radiology	4 (20%)
	Urology	2 (10%)
	Surgical Oncology	1 (5%)
	General Medicine	1 (5%)
	Surgery	1 (5%)
Visualization Techniques	Conventional Lymphoscintigraphy	
	Blue Dye Only	0 (0%)
	Radioactive tracer	2 (10%)
	Fluorescence	2 (10%)
	Combination of Blue Dye and Radioactive Tracer	1 (5%)
	Two modalities	2 (10%)
	Three modalities	2 (10%)
	Near-infrared Fluorescence/Radio-Fluorescence	5 (25%)
	SPECT/CT	6 (30%)
Identified Pathologies	Cervical, Endometrial, and Vulvar Cancer	8 (40%)
	Breast Cancer	6 (30%)
	Head and Neck Cancer	3 (15%)
	Prostate Cancer	2 (10%)
	Melanoma	1 (5%)

Half of the publications included a patient sample size of more than 100, showing that large sample size in general was correlated with success in the field. However, nine of the articles had a sample size of less than 50. Most of the study design was prospective, perhaps because SLN biopsy was not the standard of treatment in major institutions when these studies were conducted. There was also great diversity in the visualization techniques. It is interesting that authors from Japan published three of the four studies using fluorescence techniques. This technique was first described by Hiratsuka et al for imaging of gastric lymph nodes in 2001 (22). Since then, the country has become a leader in fluorescence imaging. While most of SLN biopsies were utilized for breast cancer (n=28) and melanoma (n=14), a significant number of gynecological (n=4) and gastrointestinal cancers (n=4) were also described in the publications.

A review of literature from 2010-present shows important trends in the recent development of sentinel lymph node imaging. Netherlands (n=7) produced the most highly-cited articles, followed by United States of America (n=6), Germany (n=2), and France (n=2). This suggests that the European countries are making a greater contribution to advances in the field than before. In addition, SLN biopsies are being utilized for more diverse pathologies. While SLN biopsy was traditionally used to examine mostly breast cancer and melanoma, recent literature shows that the procedure is being increasingly used for Gynecologic (n=8), Head and Neck (n=3), and Prostate (n=2) cancers. More interestingly, the visualization techniques for SLNI have also evolved. Two recent techniques in highly-cited literature are: 1) fusion imaging, which combines molecular and anatomical information, using single-photon emission computed tomography and computed tomography, known as SPECT/CT (n=6), and 2) Near-infrared fluorescence (n=5). Based on these trends, we predict that fusion imaging and near-infrared fluorescence will play an increasing role in sentinel node imaging, which will aid in the diagnosis of diverse group of cancer pathologies. One potential area of development is use of fusion imaging combining positron emission tomography and magnetic resonance imaging (PET/MRI), which may provide superior assessment of malignant lymph nodes while reducing radiation exposure.

Limitations:

Like other bibliometric studies, our study has limitations. We were interested in studies that examined the diagnostic value of SLN biopsy and therefore excluded clinical trials that examined the survivability and long-term complications such as the ALMANAC (Axillary Lymphatic Mapping Against Nodal Axillary Clearance) Trial. In addition, there are several limitations with using citation analysis. We may have underestimated the true impact of articles when the information contained in the articles becomes common knowledge so that the articles themselves are not cited anymore (23) or journals ask authors to supply only recent references. This is known as the obliteration by incorporation phenomenon. However, because SLN imaging is a relatively new area of research, we predict that this factor will not play a significant role. Another drawback of using citation analysis is that it doesn't take into account the impact of self-citations. Even though previous research indicates that self-citation may not play an important role in academic literature (24), it may play a significant role in our bibliometric analysis because half of the articles (n=25) had ten or more authors.

Furthermore, the citation counts for the top articles varied between Scopus, Web of Science and Google Scholar. We decided to use Web of Science because it was most consistent with our search criteria. Publications from earlier years were more likely to appear in our database because they had more time since publication and more likelihood to be cited. To adjust for this, we also

analyzed the publications based on their citations per year and performed another search of the literature from 2010 onwards. Furthermore, having high citation counts may not necessarily correlate perfectly with the potential influence of a publication as new publications which are scarcely-cited may evolve to play important roles in the future. Thus, performing another bibliometric analysis in the near future may help re-evaluate the impact of recently-published articles. Despite these limitations, several studies have shown the validity of using citation analysis in bibliometric studies (25-29).

CONCLUSION

Examining the top cited articles in the field of sentinel lymph node imaging (SLNI) helps clinicians and clinical researchers to conveniently identify the most influential literature. Performing a literature search of the field from 2010 onwards identifies the trajectory of SLNI as a rapidly expanding field with increasing clinical importance for the role it plays in cancer diagnosis and staging. This provides potential authors with insight into common factors of success and may enable us to predict for future trends of research in this area.

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Faisal Khosa, MD, MBA, FFRRCSI, FRCPC, DABR
Vancouver General Hospital
Jim Patterson South
899 West 12th Avenue, G861
Vancouver V5Z 1M9, BC, Canada
Tel: 604-875-4111 ext 63711
E-mail: fkhosa@gmail.com