


Bibliometric analysis of the 100 most cited articles on cervical cancer radiotherapy

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Abstract

Purpose: To identify the 100 most cited research articles on cervical cancer radiotherapy.

Methods: The Web of Science and Scopus databases were searched to identify the 100 most cited articles on cervical cancer radiotherapy as of September 29, 2019. Articles were ranked based on the total citations received from 2 databases. One hundred articles about radiotherapy for cervical cancer were identified. The following important information was extracted: author, journal, year and month of publication, country or region, and radiotherapy technologies.

Results: The 100 most cited articles on cervical cancer radiotherapy were published between 1964 and 2016, and the total citations from 2 databases ranged from 3478 to 211, including a total of 49,262 citations as of September 29, 2019. The index of citations per year ranged from 170.4 to 13.1. These articles were from 16 countries or regions, with most publications being from the United States (n=38), followed by Austria (n=15), Canada (n=8), France (n=8) and the United Kingdom (n=7). The International Journal of Radiation Oncology, Biology, Physics produced the most articles (n=42), followed by Radiotherapy and Oncology (n=13), Cancer (n=8) and Journal of Clinical Oncology (n=7). These articles were categorized as original studies (n=86), recommendations (n=5), guidelines (n=5) and reviews (n=4). Of the 100 most cited articles, intracavitary brachytherapy (n=50) and 3-dimensional conformal radiotherapy (n=34) were the most commonly used treatment techniques.

Conclusion: To the best of our knowledge, this is the first report and analysis of the most cited articles on cervical cancer radiotherapy. This bibliographic study presents the history of technological development in external radiation therapy and brachytherapy. Brachytherapy is an indispensable part of radiotherapy for cervical cancer. The International Journal of Radiation Oncology Biology Physics is the journal with the most publications related to cervical cancer radiotherapy.

Abbreviations: 3D-CRT = 3-dimensional conformal radiotherapy, CPY = citations per year, EBRT = external beam radiotherapy, EMBRACE II = image guided intensity modulated external beam radiochemotherapy and MRI based adaptive brachytherapy in locally advanced cervical cancer, IC = intracavitary, IC/IS = intracavitary-interstitial, IC/IS-BT = intracavitary and interstitial brachytherapy, IC-BT = intracavitary brachytherapy, IMRT = intensity-modulated radiation therapy, SBRT = stereotactic body radiation therapy.

Keywords: bibliometric analysis, brachytherapy, cervical cancer, external beam radiotherapy, most cited articles, VOSviewer

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1. Introduction

Cervical cancer is the fourth most common cancer among women worldwide, while in low- and medium-income countries it ranks second in both incidence and mortality.^[1] Radiotherapy for cervical cancer, especially brachytherapy, has been used for more than 100 years. The positive clinical outcomes of radical radiotherapy for cervical cancer benefit from the combination of external beam radiotherapy (EBRT) and brachytherapy, which provides a medium preventive dose in low-risk areas and a high radical dose in high-risk areas, especially in areas adjacent to sources in brachytherapy.^[2] Intensity-modulated radiation therapy (IMRT) reduces the dose to adjacent organs around the target volume, which is conducive to reducing radiation-related side effects.^[3] Compared with conventional brachytherapy, image-guided brachytherapy not only increases the dose-volume histogram parameters of target volumes, but also brings benefits to local control, and survival of patients with cervical cancer.^[4,5]

When a published article quotes another article, a citation is generated. Despite some limitations, such as self-citing from authors or journals, the quality of highly cited articles seems to be better than that of less cited articles, thus rendering citations an objective indicator.^[6,7] In this report, we use bibliometric analysis to identify the 100 most cited articles on cervical cancer radiotherapy.

2. Materials and methods

Our research did not require ethics approval because all the data in this study were based on public publications. All databases and journals included in the Web of Science and Scopus databases were used to search for eligible studies. The search strategy to identify studies on cervical cancer radiotherapy is shown in Table 1. The search time ranged from 1900 to September 29, 2019. Articles were ranked based on the total citations received from the 2 databases. One hundred articles about radiotherapy for cervical cancer were identified.

Older studies tend to accumulate a larger number of citations; thus, to account for the year and month of publication, an index of citations per year (CPY) was calculated as the total citations from 2 databases divided by the years of publication up to September 2019 for each article. The author, journal, year, and month of publication, country or region, and radiotherapy technologies were recorded. Article types were categorized into an original study, recommendation, guideline, and review. Original studies were further categorized into clinic, physics, and radiobiology. Two independent authors (Zhao HF and Zhao ZP) performed the search and extracted information from the articles. Discrepancies were resolved by consultation with a third author (Tang XD). VOSviewer (Leiden University, Leiden, Netherlands) was used to analyze the relations among coauthors who have more than 4 articles among the 100 most cited articles.

3. Results

The 100 most cited articles on cervical cancer radiotherapy were published from 1964 and 2016, and the number of citations ranged from 3478 to 211, including a total of 49,262 citations as of September 29, 2019 (Table 2). The CPY index ranged from 70.4 to 13.1. Nine articles had over 1000 citations at the time of our search; of these 9 articles, 2 are recommendations from Groupe Européen de Curiethérapie and the European Society for Radiotherapy & Oncology.^[8,9] The most cited articles were divided into 5-year periods. The 5-year period with the largest number of articles was 1999 to 2004 with 29 articles, followed by 2004 to 2009 with 22 articles (Fig. 1). The journal *International Journal of Radiation Oncology, Biology, Physics* had the highest number of articles (42 articles), followed by *Radiotherapy and Oncology* with 13 articles, *Cancer* with 8 articles and *Journal of Clinical Oncology* with 7 articles. The remaining journals (*Gynecologic Oncology*, *British Journal of Cancer*, *American Journal of Obstetrics*, and *Gynecology*, and *Brachytherapy*) each published 5 or fewer of the 100 most cited articles (see Table 3).

According to the signature unit of the first author, the 100 most cited articles on cervical cancer radiotherapy were from 17 countries or regions, with most publications being from the

United States (38 articles), followed by Austria (15 articles), Canada (8 articles), France (8 articles), and the United Kingdom (7 articles). The remaining countries or regions (Japan, Denmark, Italy, The Netherlands, Norway, Taiwan Republic of China) each published 6 or fewer of the most 100 cited articles (see Table 4).

Seventy-eight first authors contributed to articles on the 100 most cited articles. Five authors (first author) were credited with having at least 3 of the most 100 cited articles. Among these authors, Perez, CA had 6 articles, Dimopoulos, JCA had 4 articles, and Eifel, PJ, Pötter, R, and Viswanathan, AN had 3 articles. The first authors, corresponding authors and coauthors with the largest number of the 100 most cited articles are listed in Table 5. The relations among coauthorship with more than 4 of the most 100 cited articles are shown in Figure 2.

The 100 most cited articles were categorized as original studies (86 articles), recommendations (5 articles), guidelines (5 articles), and reviews (4 articles) (see Table 6). Among the 100 most cited articles, intracavitary (IC) brachytherapy and 3-dimensional conformal radiotherapy (3D-CRT) were the most commonly used treatment techniques (see Table 6). Among the 100 most cited articles, articles involving EBRT were categorized by technology, and the relationship between article number and year range of publication is shown in Figure 3. Articles involving brachytherapy were also categorized by technology, and the same relationship is shown in Figure 4. The relations among cooccurrences of no less than 2 of the most cited articles are shown in Figure 5.

The 4 recommendations from Groupe Européen de Curiethérapie and the European Society for Radiotherapy & Oncology all received a high number of citations (1819, 1659, 394, and 318; ranked 5, 6, 33, and 46) and had high CPY index values (133.1, 115.7, 53.1, and 35.0; ranked 3, 4, 14, and 25).^[8–11] Recommendations for a high dose rate from the American Brachytherapy Society published in 2000 also received a high number of citations (630, ranked 15) and a high CYP index value (33.0, ranked 28).^[12]

4. Discussion

There are several literature databases, such as the Web of Science, Google Scholar, and Scopus databases, that provide data on citation counts. Generally, Google Scholar can help to retrieve the most obscure information, but it is rarely used in systematic literature searches (such as meta-analyses, systematic review, and bibliometric analyses) due to inconsistent accuracy in the results, inadequate citation information and a lack of updates.^[13] In meta-analyses, the use of multiple databases can improve the query yield, which may reduce the chances of omitting articles of interest. Similarly, the Web of Science and the Scopus databases were used to retrieve articles in this study.

Table 1
Search strategy for literature query for cervical cancer radiotherapy.

Number	Search strategy	Web of Science	Scopus
#1	Search terms in title: MeSH term (uterine cervical neoplasms) or it is all entry terms or "carcinoma of the cervix" or "carcinoma of cervix".	37514	43638
#2	Search terms in title: MeSH terms ("brachytherapy", "radiotherapy", "radiotherapy, intensity-modulated" or "radiotherapy, conformal") or their all entry terms or "high dose rate" or "high-dose-rate" or "low dose rate" or "low-dose-rate" or "pulsed dose rate" or "pulsed-dose-rate" or "medium-dose-rate" or "medium dose rate"	142633	121107
#3	#1 and #2	4352	4202

Table 2**100 most cited cervical cancer radiotherapy articles, ranked in order of the number of total citations received from 2 databases.**

Rank	Yr	Journal	Title	TCTD	CPY (Rank)
1	1999	NEJM	Concurrent cisplatin-based radiotherapy and chemotherapy for locally advanced cervical cancer	3478	170.4 (1)
2	2000	JCO	Concurrent chemotherapy and pelvic radiation therapy compared with pelvic radiation therapy alone as adjuvant therapy after radical surgery in high-risk early-stage cancer of the cervix	2710	139.6 (2)
3	1999	JCO	Randomized comparison of fluorouracil plus cisplatin versus hydroxyurea as an adjunct to radiation therapy in stage IIB-IVA carcinoma of the cervix with negative para-aortic lymph nodes: a gynecologic oncology group and southwest oncology group study	2145	105.5 (6)
4	1997	LAN	Randomised study of radical surgery versus radiotherapy for stage IB-IIA cervical cancer	2104	95.3 (8)
5	2006	RO	Recommendations from gynaecological (GYN) GEC ESTRO working group (II): concepts and terms in 3D image-based treatment planning in cervix cancer brachytherapy - 3D dose volume parameters and aspects of 3D image-based anatomy, radiation physics, radiobiology	1819	133.1 (3)
6	2005	RO	Recommendations from gynaecological (GYN) GEC-ESTRO working group (I): concepts and terms in 3D image based 3D treatment planning in cervix cancer brachytherapy with emphasis on MRI assessment of GTV and CTV	1659	115.7 (4)
7	2001	LAN	Survival and recurrence after concomitant chemotherapy and radiotherapy for cancer of the uterine cervix: a systematic review and meta-analysis	1541	85.6 (9)
8	2004	JCO	Pelvic irradiation with concurrent chemotherapy versus pelvic and para-aortic irradiation for high-risk cervical cancer: an update of radiation therapy oncology group trial (RTOG) 90-01	1277	82.4 (10)
9	1999	GO	A randomized trial of pelvic radiation therapy versus no further therapy in selected patients with stage IB carcinoma of the cervix after radical hysterectomy and pelvic lymphadenectomy: a gynecologic oncology group study	1231	60.5 (12)
10	2011	RO	Clinical outcome of protocol based image (MRI) guided adaptive brachytherapy combined with 3D conformal radiotherapy with or without chemotherapy in patients with locally advanced cervical cancer	841	103.0 (7)
11	2007	RO	Clinical impact of MRI assisted dose volume adaptation and dose escalation in brachytherapy of locally advanced cervix cancer	706	57.2 (13)
12	2002	JCO	Phase III trial comparing radical radiotherapy with and without cisplatin chemotherapy in patients with advanced squamous cell cancer of the cervix	700	39.8 (22)
13	1991	CA	Carcinoma of the cervix treated with radiation therapy I: a multi-variate analysis of prognostic variables in the gynecologic oncology group	671	23.8 (43)
14	2001	IJROBP	Intensity-modulated radiation therapy (IMRT) reduces small bowel, rectum, and bladder doses in patients with cervical cancer receiving pelvic and para-aortic irradiation	651	36.2 (24)
15	2000	IJROBP	The American Brachytherapy Society recommendations for high-dose-rate brachytherapy for carcinoma of the cervix	630	33.0 (28)
16	1999	CA	The importance of hemoglobin levels during radiotherapy for carcinoma of the cervix	621	31.2 (30)
17	2007	IJROBP	Computed tomography versus magnetic resonance imaging-based contouring in cervical cancer brachytherapy: results of a prospective trial and preliminary guidelines for standardized contours	602	49.1 (18)
18	1995	IJROBP	Time course and incidence of late complications in patients treated with radiation therapy for FIGO Stage IB carcinoma of the uterine cervix	550	22.8 (44)
19	1985	JNCI	Second cancers following radiation treatment for cervical cancer. An international collaboration among cancer registries	537	15.6 (61)
20	1984	CA	Radiation therapy alone in the treatment of carcinoma of the uterine cervix. II. Analysis of complications	534	15.0 (62)
21	2002	JCO	Neoadjuvant chemotherapy and radical surgery versus exclusive radiotherapy in locally advanced squamous cell cervical cancer: results from the Italian multicenter randomized study	533	30.2 (32)
22	1995	IJROBP	Carcinoma of the uterine cervix. I. Impact of prolongation of overall treatment time and timing of brachytherapy on outcome of radiation therapy	517	21.4 (48)
23	1999	NEJM	Improved treatment for cervical, cancer - Concurrent chemotherapy and radiotherapy	503	24.6 (41)
24	2005	IJROBP	Dose and volume parameters for MRI-based treatment planning in intracavitary brachytherapy for cervical cancer	485	34.2 (27)
25	1993	IJROBP	The influence of treatment time on outcome for squamous cell cancer of the uterine cervix treated with radiation: a patterns-of-care study	473	17.8 (56)
26	1983	CA	Radiation therapy alone in the treatment of carcinoma of uterine cervix I. Analysis of tumor recurrence	450	12.5 (75)
27	2002	IJROBP	Measurement of tumor volume by PET to evaluate prognosis in patients with advanced cervical cancer treated by radiation therapy	437	25.3 (40)
28	1991	JCO	A randomized trial of chemotherapy followed by pelvic radiation therapy in stage IIIB carcinoma of the cervix	417	14.8 (64)
29	2008	IJROBP	Consensus guidelines for delineation of clinical target volume for intensity-modulated pelvic radiotherapy in postoperative treatment of endometrial and cervical cancer	412	36.6 (23)
30	2012	BRA	American brachytherapy society consensus guidelines for locally advanced carcinoma of the cervix. Part II: high-dose-rate brachytherapy	403	52.6 (15)
31	2003	IJROBP	Longitudinal study of sexual function and vaginal changes after radiotherapy for cervical cancer	397	24.6 (42)
32	2011	IJROBP	Consensus guidelines for delineation of clinical target volume for intensity-modulated pelvic radiotherapy for the definitive treatment of cervix cancer	397	46.3 (20)
33	2012	RO	Recommendations from gynaecological (GYN) GEC-ESTRO working group (IV): basic principles and parameters for MR imaging within the frame of image based adaptive cervix cancer brachytherapy	394	53.1 (14)

(continued)

Table 2
(continued).

Rank	Yr	Journal	Title	TCTD	CPY (Rank)
34	2012	BRA	American Brachytherapy Society consensus guidelines for locally advanced carcinoma of the cervix. Part I: general principles	381	49.7 (17)
35	1976	AJOG	Radical pelvic surgery versus radiation therapy for stage I carcinoma of the cervix (exclusive of microinvasion)	369	8.5 (91)
36	2013	IJROBP	Trends in the utilization of brachytherapy in cervical cancer in the United States	367	61.2 (11)
37	2006	IJROBP	The Vienna applicator for combined intracavitary and interstitial brachytherapy of cervical cancer: Design, application, treatment planning, and dosimetric results	365	27.5 (36)
38	2005	CDSR	Concomitant chemotherapy and radiation therapy for cancer of the uterine cervix	364	25.7 (39)
39	1999	IJROBP	FIGO IIB squamous cell carcinoma of the cervix: an analysis of prognostic factors emphasizing the balance between external beam and intracavitary radiation therapy	362	17.7 (57)
40	2012	RO	Impact of 3D image-based PDR brachytherapy on outcome of patients treated for cervix carcinoma in France: results of the French STIC prospective study	342	47.2 (19)
41	2009	RO	Dose-effect relationship for local control of cervical cancer by magnetic resonance image-guided brachytherapy	341	34.7 (26)
42	1978	BJR	Hyperbaric oxygen and radiotherapy: a medical research council trial in carcinoma of the cervix	338	8.3 (93)
43	2008	IJROBP	MRI-guided 3D optimization significantly improves DVH parameters of pulsed-dose-rate brachytherapy in locally advanced cervical cancer	334	29.9 (33)
44	2006	IJROBP	Dosimetric predictors of acute hematologic toxicity in cervical cancer patients treated with concurrent cisplatin and intensity-modulated pelvic radiotherapy	333	26.1 (37)
45	2016	RO	Image guided brachytherapy in locally advanced cervical cancer: improved pelvic control and survival in RetroEMBRACE, a multicenter cohort study	323	107.7 (5)
46	2010	RO	Recommendations from gynaecological (GYN) GEC-ESTRO working group: Considerations and pitfalls in commissioning and applicator reconstruction in 3D image-based treatment planning of cervix cancer brachytherapy	318	35.0 (25)
47	1994	IJROBP	Low dose rate versus high dose rate brachytherapy in the treatment of carcinoma of the uterine cervix: a clinical trial	315	12.3 (76)
48	1991	IJROBP	Comparison of high and low dose rate remote afterloading for cervix cancer and the importance of fractionation	315	11.3 (81)
49	1993	BJC	Intrinsic radiosensitivity and prediction of patient response to radiotherapy for carcinoma of the cervix	313	12.1 (77)
50	1986	CA	Carcinoma of the cervix, stage III. Results of radiation therapy	312	9.3 (85)
51	2002	CO	Concurrent cisplatin-based chemotherapy plus radiotherapy for cervical cancer: a meta-analysis	311	18.0 (54)
52	2009	IJROBP	Dose-volume histogram parameters and local tumor control in magnetic resonance image-guided cervical cancer Brachytherapy	306	30.6 (31)
53	2013	AO	MRI-guided adaptive radiotherapy in locally advanced cervical cancer from a Nordic perspective	305	51.5 (16)
54	2003	CCR	Overexpression of hypoxia-inducible factor 1 alpha indicates diminished response to radiotherapy and unfavorable prognosis in patients receiving radical radiotherapy for cervical cancer	303	18.6 (52)
55	1986	GO	Radiation therapy alone in the treatment of carcinoma of the uterine cervix: a 20-year experience	302	9.0 (88)
56	2000	BJC	Hypoxia-induced treatment failure in advanced squamous cell carcinoma of the uterine cervix is primarily due to hypoxia induced radiation resistance rather than hypoxia-induced metastasis	299	15.7 (60)
57	1983	BJR	Carcinoma of the cervix: anaemia, radiotherapy and hyperbaric oxygen	297	8.2 (94)
58	1999	IJROBP	Radiation therapy morbidity in carcinoma of the uterine cervix: dosimetric and clinical correlation	292	14.5 (67)
59	2006	IJROBP	The Vienna applicator for combined intracavitary and interstitial brachytherapy of cervical cancer: clinical feasibility and preliminary results	291	22.4 (46)
60	1992	CA	High-dose-rate remote afterloading intracavitary radiation therapy for cancer of the uterine cervix. A 20-year experience	289	10.4 (83)
61	1989	IJROBP	Prognostic value of hemoglobin concentrations and blood transfusions in advanced carcinoma of the cervix treated by radiation therapy: results of a retrospective study of 386 patients	283	9.2 (87)
62	1964	AJOG	Complications following radiation therapy in carcinoma of the cervix and their treatment. Joseph price oration	277	5.0 (98)
63	1988	IJROBP	Radiotherapy alone in carcinoma of the intact uterine cervix according to G. H. Fletcher guidelines: a French cooperative study of 1383 cases	276	8.8 (90)
64	2010	RO	From point A to the sculpted pear: MR image guidance significantly improves tumour dose and sparing of organs at risk in brachytherapy of cervical cancer	275	28.7 (34)
65	2006	IJROBP	Conventional, conformal, and intensity-modulated radiation therapy treatment planning of external beam radiotherapy for cervical cancer: the impact of tumor regression	273	20.0 (51)
66	2001	IJROBP	Elevated cyclooxygenase-2 expression correlates with diminished survival in carcinoma of the cervix treated with radiotherapy	270	14.7 (65)
67	1990	GO	Adjuvant radiotherapy following radical hysterectomy for patients with stage IB and IIA cervical cancer	270	9.2 (86)
68	1997	BJC	The independence of intrinsic radiosensitivity as a prognostic factor for patient response to radiotherapy of carcinoma of the cervix	262	12.0 (78)
69	1983	IJROBP	Treatment of carcinoma of the uterine cervix by remotely controlled afterloading intracavitary radiotherapy with high-dose rate: a comparative study with a low-dose rate system	260	7.1 (96)
70	2000	BJC	Vascular endothelial growth factor (VEGF) expression is a prognostic factor for radiotherapy outcome in advanced carcinoma of the cervix	258	13.6 (71)
71	2008	IJROBP		257	22.5 (45)

(continued)

Table 2
(continued).

Rank	Yr	Journal	Title	TCTD	CPY (Rank)
72	2003	RO	Inter- and intrafractional tumor and organ movement in patients with cervical cancer undergoing radiotherapy: a cinematic-MRI point-of-interest study Bladder and rectum dose defined from MRI based treatment planning for cervix cancer brachytherapy: comparison of dose-volume histograms for organ contours and organ wall, comparison with ICRU rectum and bladder reference point	256	16.0 (59)
73	2000	RA	Dynamic contrast-enhanced MR imaging of uterine cervical cancer: pharmacokinetic analysis with histopathologic correlation and its importance in predicting the outcome of radiation therapy	253	13.3 (73)
74	1997	IJROBP	Carcinoma of the intact uterine cervix treated with radiotherapy alone. A French cooperative study: update and multivariate analysis of prognostics factors	246	11.1 (82)
75	2002	CR	Expression of cIAP1, a target for 11q22 amplification, correlates with resistance of cervical cancers to radiotherapy	246	14.5 (68)
76	2005	IJROBP	Comparison between CT-based volumetric calculations and ICRU reference-point estimates of radiation doses delivered to bladder and rectum during intracavitary radiotherapy for cervical cancer	244	17.0 (58)
77	2011	IJROBP	Dose-volume histogram parameters and late side effects in magnetic resonance image-guided adaptive cervical cancer brachytherapy	243	28.3 (35)
78	2002	IJROBP	Prediction of radiotherapy outcome using dynamic contrast enhanced MRI of carcinoma of the cervix	242	14.4 (69)
79	2006	GO	Surgery after concurrent chemoradiotherapy and brachytherapy for the treatment of advanced cervical cancer: morbidity and outcome: results of a multicenter study of the GCCLCC (groupe des chirurgiens de centre de lutte contre le cancer)	241	18.5 (53)
80	2010	IJROBP	Clinical outcomes of definitive intensity-modulated radiation therapy with fluorodeoxyglucose-positron emission tomography simulation in patients with locally advanced cervical cancer	239	26.1 (38)
81	1995	RO	Prognostic factors in patients with cervix cancer treated by radiation therapy: results of a multiple regression analysis	239	9.8 (84)
82	2012	IJROBP	Dose effect relationship for late side effects of the rectum and urinary bladder in magnetic resonance image-guided adaptive cervix cancer brachytherapy	238	31.4 (29)
83	1965	RA	Influence of anemia on results of radiotherapy in carcinoma of cervix	237	4.4 (100)
84	2002	JCO	Correlation of smoking history and other patient characteristics with major complications of pelvic radiation therapy for cervical cancer	235	13.8 (70)
85	2008	IJROBP	Dosimetric comparison of bone marrow-sparing intensity-modulated radiotherapy versus conventional techniques for treatment of cervical cancer	235	21.2 (50)
86	1989	GO	Complications of combined radical hysterectomy. Postoperative radiation therapy in women with early stage cervical cancer	229	7.5 (95)
87	1994	IJROBP	Erythropoietin increases hemoglobin during radiation therapy for cervical cancer	226	9.0 (89)
88	2009	IJROBP	Physics contributions and clinical outcome with 3D-MRI-based pulsed-dose-rate intracavitary brachytherapy in cervical cancer patients	224	21.7 (47)
89	2001	RO	Comparison of radiography- and computed tomography-based treatment planning in cervix cancer in brachytherapy with specific attention to some quality assurance aspects	223	11.9 (79)
90	2000	JMRI	Pixel analysis of MR perfusion imaging in predicting radiation therapy outcome in cervical cancer	223	11.9 (80)
91	2007	IJROBP	Clinical outcome in posthysterectomy cervical cancer patients treated with concurrent cisplatin and intensity modulated pelvic radiotherapy: comparison with conventional radiotherapy	221	17.8 (55)
92	1993	CA	High-dose rate and low-dose rate intracavitary therapy for carcinoma of the uterine cervix. Final results of Osaka university hospital	220	8.5 (92)
93	1975	AJOG	Radical hysterectomy or radiotherapy for Stage I cervical cancer. A prospective comparison with 5 and 10 year follow-up	219	4.9 (99)
94	2004	IJROBP	Recurrent squamous cell carcinoma of cervix after definitive radiotherapy	218	14.5 (66)
95	2005	CA	Long-term results of high-dose rate intracavitary brachytherapy for squamous cell carcinoma of the uterine cervix	218	14.9 (63)
96	1988	IJROBP	Analysis of pelvic tumor control and impact on survival in carcinoma of the uterine cervix treated with radiation therapy alone	218	6.9 (97)
97	2003	IJROBP	Significant correlation of hypoxia-inducible factor-1 alpha with treatment outcome in cervical cancer treated with radical radiotherapy	217	13.4 (72)
98	2009	EJC	Hyperthermia dose-effect relationship in 420 patients with cervical cancer treated with combined radiotherapy and hyperthermia	216	21.2 (49)
99	2014	IJROBP	National cancer data base analysis of radiation therapy consolidation modality for cervical cancer: the impact of new technological advancements	212	44.6 (21)
100	2003	IJROBP	Epidermal growth factor receptor (EGFR) and vascular endothelial growth factor (VEGF) negatively affect overall survival in carcinoma of the cervix treated with radiotherapy	211	13.1 (74)

AJOG = American Journal of Obstetrics and Gynecology, AO = Acta Oncologica, BJC = British Journal of Cancer, BJR = British Journal of Radiology, BRA = Brachytherapy, CA = cancer, CCR = clinical cancer research, CDSR = Cochrane Database of systematic reviews, CO = clinical oncology, CPY = citations per year, CR = cancer research, EJC = European Journal of Cancer, GO = Gynecologic Oncology, IJROBP = International Journal of Radiation Oncology Biology Physics, JCO = journal of clinical oncology, JMRI = journal of magnetic resonance imaging, JNCI = Journal of the National Cancer Institute, LAN = Lancet, NEJM = New England Journal of Medicine, Ra = radiology, RO = radiotherapy and oncology, TCTD = Total citations from 2 databases.

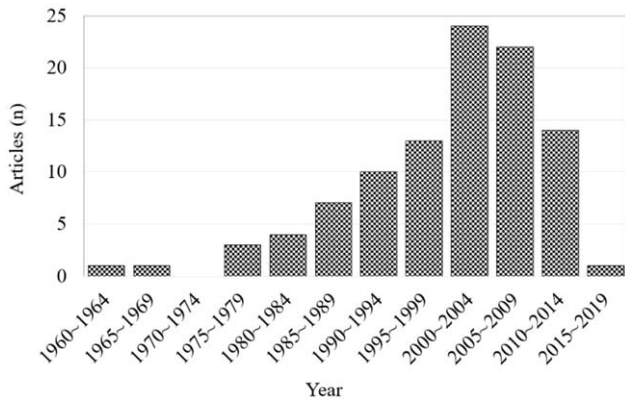


Figure 1. Frequency chart for each 5-year period for the 100 most cited articles on cervical cancer radiotherapy.

For locally advanced cervical cancer, concomitant chemotherapy, and radiation therapy is the modern treatment modality. EBRT and brachytherapy are 2 indispensable treatment modalities in radiotherapy.^[14-17] Delineation of the clinical target volume has always been an important topic in radiotherapy. Two articles about delineation of clinical target volume for IMRT postoperative and definitive treatment were both listed in the 100 most cited articles.^[14,18] For brachytherapy, recommendations for delineation of target volumes, such as high-risk clinical target volume, and intermediate-risk clinical target volume, were also included in the 100 most cited articles.^[9] The high citations of these articles adequately illustrated the importance of target delineation.

In the earlier period, EBRT used large anterior and posterior opposed fields.^[19] With the advancement of radiotherapy equipment technology, such as multileaf collimator and computer-aided treatment planning systems, 3D-CRT has gradually been applied. IMRT has emerged with further advances in treatment

Table 4

Countries or region of origin of the 100 most cited articles in the field of cervical cancer radiotherapy.

Country or region	Number of articles
United States	38
Austria	15
Canada	8
France	8
United Kingdom	7
Japan	6
Denmark	4
Italy	2
The Netherlands	2
Norway	2
Taiwan, China	2
Brazil	1
Greece	1
India	1
South Africa	1
Sweden	1
Switzerland	1

technologies, such as inverse treatment planning systems and control systems of linear accelerators. Small bowel, rectum, bladder and bone marrow sparing with IMRT is superior to a conventional beam arrangement with a similar target coverage.^[3,20] As shown in Figure 3, among the 100 most cited articles, article involving conventional radiotherapy were first published in 1965 to 1969, 3D-CRT technology was first mentioned in 1980 to 1984, and IMRT technology was first mentioned in 2000 to 2004.

Table 5

Number of authorships of the 100 most frequently cited articles on the field of cervical cancer radiotherapy.

Description	Author name (number of articles)
Most frequent first author	Perez, CA (6)
	Dimopoulos, JCA (4)
	Eifel, PJ (3)
	Potter, R (3)
	Viswanathan, AN (3)
	Gaffney, DK (2)
	Georg, P (2)
	Green, JA (2)
	Kirisits, C (2)
	Lindegaard, JC (2)
	Loncaster, JA (2)
	Mell, LK (2)
	West, CML (2)
	Most frequent corresponding author
Eifel, PJ (5)	
Potter, R (5)	
Dimopoulos, JCA (4)	
West, CML (4)	
Most frequent coauthor (total)	Potter, R (17)
	Kirisits, C (16)
	Dimopoulos, JCA (13)
	Lang, S (10)
	Berger, D (9)
	Georg, P (8)
	Grigsby, PW (6)
	Haie-meder, C (6)
Perez, CA (6)	
Tanderup, K (6)	

Table 3

Journals in which the 100 most cited cervical cancer radiotherapy articles were published.

Journal	Number of articles	Impact factor in 2019
International journal of radiation oncology biology physics	42	6.203
Radiotherapy and oncology	13	5.252
Cancer	8	6.102
Journal of clinical oncology	7	28.245
Gynecologic oncology	5	4.393
British journal of cancer	4	5.416
American journal of obstetrics and gynecology	3	6.120
Brachytherapy	2	2.03
British journal of radiology	2	1.939
Lancet	2	59.102
New England journal of medicine	2	70.67
Radiology	2	7.608
Acta Oncologica	1	3.298
Cancer research	1	8.378
Clinical cancer research	1	8.911
Clinical oncology	1	3.047
Cochrane database of systematic reviews	1	7.755
European journal of cancer	1	6.68
Journal of magnetic resonance imaging	1	3.732
Journal of the national cancer institute	1	10.211

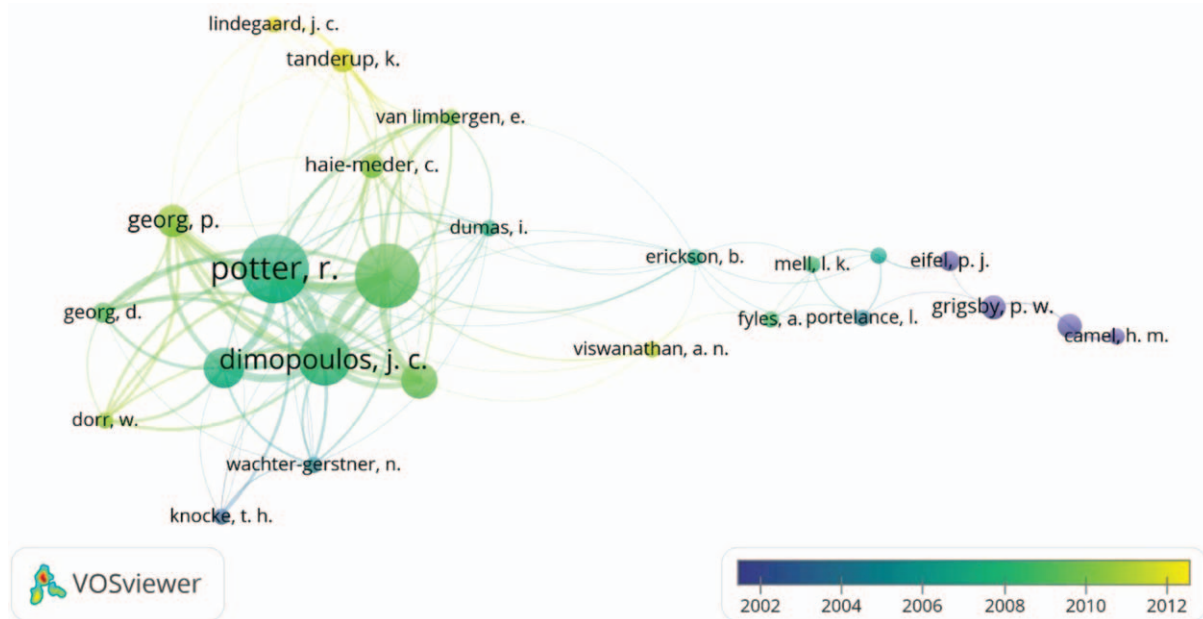


Figure 2. The network visualization of coauthors from the 100 most cited articles according to the average published year. The circle size represents the number of articles in the 100 most cited articles. The larger the circle is, the more articles the author has published. The width of the curved line represents the link strength. The wider the line is, the more links there are. The distance between 2 authors approximately indicates the relatedness of the nodes.

In a European study on magnetic resonance imaging (MRI)-guided brachytherapy in locally advanced cervical cancer, IMRT was not mandatory, and clinical outcome benchmarks were established. In image-guided intensity-modulated external beam radiochemotherapy and MRI-based adaptive brachytherapy in locally advanced cervical cancer (EMBRACE II), IMRT and daily image guided radiotherapy were mandatory. With daily image guided radiotherapy and couch correction, a margin reduction from 10 to 5 mm can be performed without compromising target coverage.^[21]

As shown in Figure 4, among the 100 most cited articles, an article involving intracavitary brachytherapy (IC-BT) was first

published in 1960 to 1964, while intracavitary and interstitial brachytherapy (IC/IS-BT) was first mentioned in 2000 to 2004. In the early period, IC-BT had a pear-shaped absorbed dose distribution using standard source loading, and the prescribed dose was delivered to point A of the Manchester system.^[22] With the application of 3D imaging, IC-BT can be optimized to the sculpted pear dose, increasing the dose to target volumes and reducing the dose to organs at risk.^[4,23] However, the optimization of IC-BT has some limitations due to the high dose gradient of brachytherapy. In practice, the planning-aim isodose cannot be placed more than 25 mm from the tandem at the level of Point A.^[24,25] Combined intracavitary-interstitial (IC/IS) applicators have been developed for targeting tumors that are not well covered by IC applicators.^[26-29] IC/IS applicators allow for improved dose conformity, and target dose escalation and/or dose de-escalation in organs at risk can be carried out.^[27,30] The use of IC/IS-BT in large tumors significantly increased local control without increasing morbidity.^[31] Based on these advantages, in the EMBRACE II study, the proportion of IC/IS-BT was increased (from 21% to more than 30%) to meet the planning aims and dose-volume histogram constraints of EMBRACE II.

Eleven authors (total coauthor) were credited with having no fewer than 6 articles on the 100 most cited articles. As shown in Figure 2, among these authors, at the time of publication, Potter R, Kirisits C, Dimopoulos JCA, Lang S, Berger D, and Georg P are all from the Medical University of Vienna, Austria. These authors have 17, 16, 13, 10, 9, and 8 articles among the 100 most cited articles, respectively. Their articles are mostly about brachytherapy. From the concentration of authors' distribution, we can see that the Medical University of Vienna contributes most to radiotherapy, especially brachytherapy, for cervical cancer and leads to the development of new technologies.

We have published 2 articles on bibliometric analysis in Brachytherapy and Journal of Contemporary Brachytherapy, respectively, on cervical cancer brachytherapy^[32] and prostate

Table 6
Type of study or technology of the 100 most cited articles on cervical cancer radiotherapy.

Article type / technology	Number of Articles
Original study	86
Clinic	72
Physics	5
Radiobiology	9
Recommendation	5
Guideline	5
Review	4
Brachytherapy involved	77*
IC-BT	50
IC/IS-BT	20
Not specified	7
External beam radiotherapy involved	55*
Conventional radiotherapy	7†
3D-conformal radiotherapy	34†
Intensity modulated radiotherapy	10†
Not specified	10†

* Some articles have external beam radiotherapy and brachytherapy involved.

† Some articles have more than 1 technology involved.

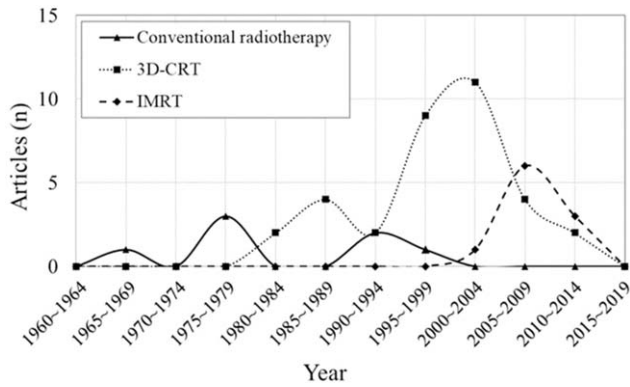


Figure 3. The 100 most cited articles (involving external beam radiotherapy), categorized by technology.

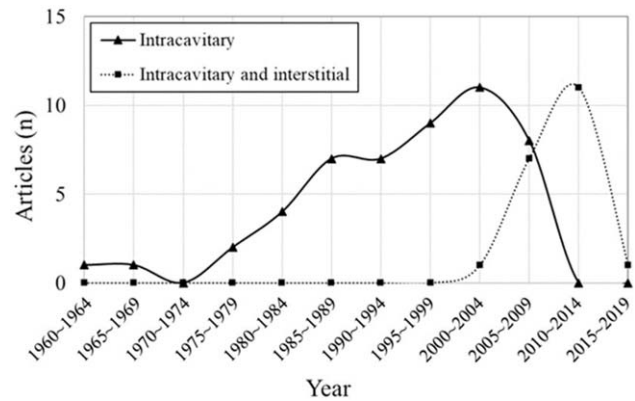


Figure 4. The 100 most cited articles (involving brachytherapy), categorized by technology.

cancer brachytherapy.^[33] Through such a bibliometric analysis of the most cited articles,^[34,35] we can observe technical progress over a long period of time, the current situation and future directions of this field. These articles can broaden the horizon and the overall thinking in this field among young doctors. The current article can be used as a first step into this area and to keep track of top organizations, authors, and publications in the field, as well as hot issues in the field.

In the cocurrence diagram of Figure 5, out of 140 occurrences, the item “brachytherapy” has appeared 10 times. This indicates that brachytherapy plays an important role in the radiotherapy of cervical cancer and is indispensable. Han et al^[16] reported that in the matched cohort between 2000 and 2009 (median follow-up 3.4 years), brachytherapy treatment was associated with a higher 4-year cause-specific survival rate

(64.3% vs 51.5%, $P < .001$) and overall survival rates (58.2% vs 46.2%, $P < .001$). An analysis of the National Cancer Data showed that from 2004 to 2010, new technologies, such as IMRT or stereotactic body radiation therapy (SBRT), have been increasingly used for boost after pelvic EBRT. However, the median survival of patients who received brachytherapy was significantly higher than that of patients who underwent IMRT or SBRT boost (70.9 vs 47.1 months, $P = .01$).^[17] With the development of EBRT technology, especially the application of SBRT boost technology in the treatment of cervical cancer, the curative effect of patients with SBRT or IMRT boost is also improved. An updated propensity score matching study based on National Cancer Data showed no significant difference in overall survival for patients who received SBRT boost versus BT boost (hazard ratio=1.477, 95% confidence interval=0.746–2.926,

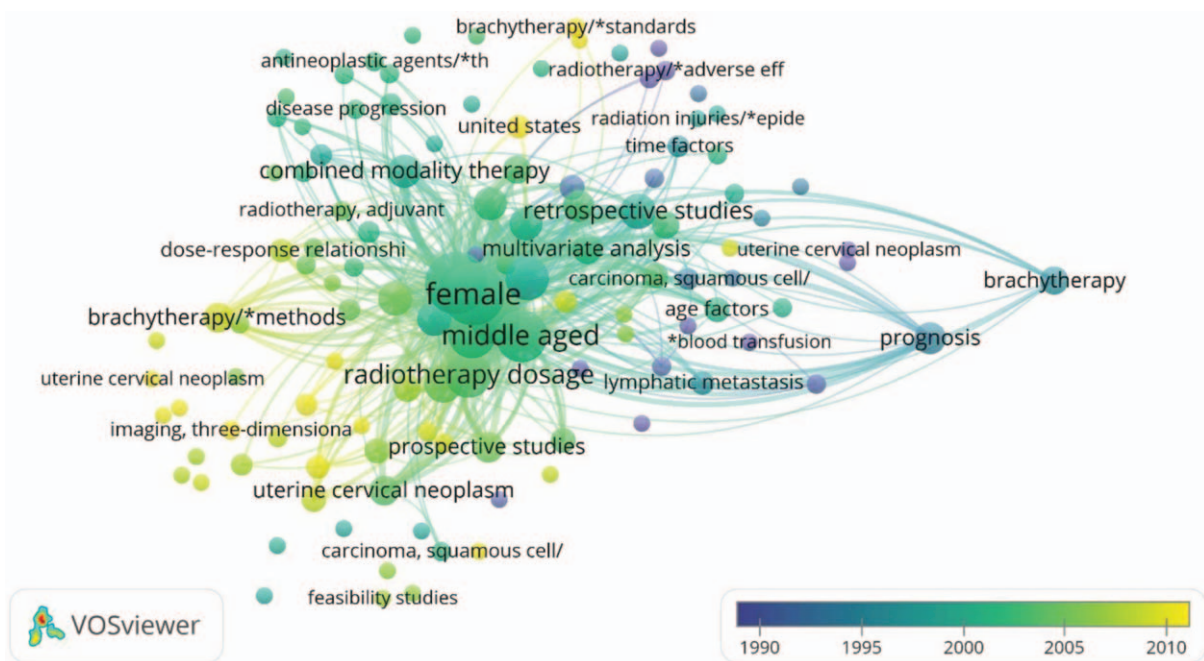


Figure 5. The network visualization of keywords from the 100 most cited articles according to the average published year. The circle size represents the number of occurrences in the 100 most cited articles. The larger the circle is, the greater the occurrence. The width of the curved line represents the link strength. The wider the line is, the more links there are. The distance between 2 occurrences approximately indicates the relatedness of the nodes.

$P=.263$) but a significant overall survival detriment in patients who received IMRT boost versus brachytherapy boost (hazard ratio=1.455, 95% confidence interval=1.300–1.628, $P<.001$).^[36] Compared with the research data of Gill et al,^[17] this study increased the data from 2011 to 2013. In addition, the patients who received SBRT boost and IMRT boost were separated in propensity-matched Kaplan–Meier analysis. This indicates that SBRT technology has made great progress in recent years. At the same time, SBRT technology is much more effective than IMRT in boost after EBRT. Therefore, SBRT has the potential of alternative therapy in patients who are not suitable for brachytherapy. This hypothesis was also preliminarily confirmed by Hsieh et al.^[37] They retrospectively analyzed 9 brachytherapy-unsuitable cervical cancers treated with definitive whole pelvic radiotherapy followed by SBRT boost via helical tomotherapy. The locoregional control rate at 3 year was 78%. Only 2 patients had residual tumors after treatment, and the others were tumor-free. Two patients experienced grade 3 acute toxicity, and no grade 3 or 4 chronic toxicity was found. Compared with IMRT, SBRT can give a higher equivalent biological dose under the same dose constraints to normal tissues due to the application of a multiple field setup and/or flattening filter-free mode. A higher dose gradient in brachytherapy is one of the factors for good tumor control by external irradiation combined with brachytherapy. A study from Dyk, P et al^[38] indicated that the total dose delivered to the gross tumor volume from combined MRI-guided high dose rate and positron emission tomography/computed tomography-guided IMRT is highly correlated with local tumor control. When the dose to the peripheral area of high-risk tumor volume (HR-CTV) reaches the prescribed dose, the dose to gross tumor volume will reach a very high level, due to the high dose gradient in brachytherapy. This is why the dwell times in needles are normally limited to 10%–20% of that used for dwell positions in the intracavitary part in the IC/IS-BT, to provide a higher dose at the center of the implant from the intracavitary components while homogeneously covering the lateral parametrial disease.^[23,27]

This study has some limitations. First, although we used 2 databases to identify articles, articles have different numbers of citations in different databases due to coverage differences. Although the retrieval based on 2 databases can increase the comprehensiveness of the literature query, there is a large overlap in the number of citations in the 2 databases. Second, since the number of citations usually increases with time, the earlier articles potentially have an artificially higher impact than the more recent articles. To counter this effect, we also used the CPY index to rerank the identified articles. Third, we cannot exclude self-citation from journals and authors.

5. Conclusions

To the best of our knowledge, this report describes the first bibliometric analysis of the 100 most cited articles on cervical cancer radiotherapy. Our study presents a detailed list and an analysis of the 100 most cited articles on cervical cancer radiotherapy to provide, insight into historical developments and enable important advances in this field to be recognized. Brachytherapy is an indispensable part of radiotherapy for cervical cancer. The International Journal of Radiation Oncology Biology Physics is the journal with the most publications related to cervical cancer radiotherapy. The Medical University of Vienna had the most achievements on cervical cancer radiother-

apy, especially brachytherapy, and may be a good candidate for collaborative research in this field.

Author contributions

Data analysis: Zhipeng Zhao, Hongfu Zhao.

Data curation: Zhipeng Zhao, Xiaodi Tang, Hongfu Zhao.

Methodology: Xiaodi Tang, Xin Mu.

Project administration: Hongfu Zhao.

Software: Xin Mu.

Supervision: Hongfu Zhao.

Writing – original draft: Zhipeng Zhao, Xiaodi Tang.

Writing – review & editing: Hongfu Zhao.

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