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 = 60) 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

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 clinics, 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.[18, 19] 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 Radiation Therapy 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).

Eighty-seven 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, Potter, 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). 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 CPY 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.
| 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 | 2719 | 139.6 (2) |
| 3    | 1999| JCO     | Randomized comparison of fluorouracil plus hydroxyurea as an adjunct to radiation therapy in stage IB-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-IA cervical cancer | 2104 | 95.3 (8)  |
| 5    | 2006| RO      | Recommendations from gynaecological (SYN) 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 (SYN) GEC-ESTRO working group (II): 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 II 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| UROBP   | 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| UROBP   | 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| UROBP   | Computed tomography versus magnetic resonance imaging-based contouring in cervical cancer brachytherapy: results of a prospective trial and preliminary guidelines for standardization of contours | 602  | 49.1 (18) |
| 18   | 1995| UROBP   | Time course and incidence of late complications in patients treated with radiation therapy for FIGO Stage IB carcinoma of the uterine cervix | 550  | 22.9 (44) |
| 19   | 1985| JNCl    | 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| UROBP   | 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| UROBP   | Dose and volume parameters for MRI-based treatment planning in intracavitary brachytherapy for cervical cancer | 485  | 34.2 (27) |
| 25   | 1993| UROBP   | 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| UROBP   | 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| UROBP   | Consensus guidelines for delineation of clinical target volume for intensity-modulated pelvic radiotherapy in postoperative treatment of endometrial and cervical cancer | 412  | 38.6 (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| UROBP   | Longitudinal study of sexual function and vaginal changes after radiotherapy for cervical cancer | 397  | 24.6 (42) |
| 32   | 2011| UROBP   | 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 (SYN) 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)
| 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  | UJROBP  | Trends in the utilization of brachytherapy in cervical cancer in the United States | 367  | 61.2 (11)  |
| 37   | 2006  | UJROBP  | 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  | UJROBP  | FIGO IIIB 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  | UJROBP  | MRI-guided 3D optimization significantly improves DVH parameters of pulsed-dose-rate brachytherapy in locally advanced cervical cancer | 334  | 29.9 (33)  |
| 44   | 2006  | UJROBP  | 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 PetroEMBRACE, 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  | UJROBP  | 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  | UJROBP  | 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  | UJROBP  | Dose-volume histogram parameters and local tumor control in magnetic resonance image-guided cervical cancer Brachytherapy | 306  | 30.6 (31)  |
| 53   | 2013  | AD      | MRI-guided adaptive radiotherapy in locally advanced cervical cancer from a Nordic perspective | 305  | 51.5 (16)  |
| 54   | 2003  | CR      | 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  | UJROBP  | Radiation therapy morbidity in carcinoma of the uterine cervix: dosimetric and clinical correlation | 292  | 14.5 (67)  |
| 59   | 2006  | UJROBP  | 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  | UJROBP  | 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  | UJROBP  | 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  | UJROBP  | 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  | UJROBP  | Elevated cyclooxygenase-2 expression correlates with diminished survival in carcinoma of the cervix treated with radiotherapy | 270  | 14.7 (65)  |
| 67   | 1990  | GO      | Adjunct radiotherapy following radical hysterectomy for patients with stage IB and IA 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  | UJROBP  | 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  | UJROBP  | (continued) | 257  | 22.5 (45)  |
Table 2 (continued).

| Rank | Yr | Journal | Title | TCTD | CPY (Rank) |
|------|----|---------|-------|------|------------|
| 72   | 2003 | RO | Bladder and rectum dose defined from MRI based treatment planning for cervix cancer brachytherapy: a cinematic-MRI point-of-interest study | 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 cervix cancer brachytherapy | 243 | 28.3 (35) |
| 78   | 2002 | IJROBP | Prediction of radiotherapy outcome using dynamic contrast enhanced MRI 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 (70) |
| 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 post hysterectomy 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 cervix 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   | 1968 | 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, BMA = Brachytherapy, CA = cancer, CCR = clinical cancer research, CDSR = Cochrane Database of systematic reviews, CO = clinical oncology, CPI = 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.
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.\cite{14-17} Delineation the of 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.\cite{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.\cite{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.\cite{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 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.\cite{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 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 | 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 1. Frequency chart for each 5-year period for the 100 most cited articles on cervical cancer radiotherapy.

### 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                  |

### 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)                    |
|                      | Voelzengarten, AN (3)            |
|                      | Gaffney, DK (2)                  |
|                      | Georg, P (2)                     |
|                      | Green, JA (2)                    |
|                      | Kirisits, C (2)                  |
|                      | Lindegaard, JC (2)               |
|                      | Lancaster, JA (2)                |
|                      | Mell, LK (2)                     |
|                      | West, OML (2)                    |
| Most frequent corresponding author          | Perez, CA (6)                    |
|                      | Eifel, PJ (5)                    |
|                      | Potter, R (5)                    |
|                      | Dimopoulos, JCA (4)              |
|                      | West, OML (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)                  |
|                      | Halse-mader, C (6)               |
|                      | Perez, CA (6)                    |
|                      | Tanderup, K (6)                  |
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-BT allows 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.
cancer brachytherapy. Through such a bibliometric analysis of the most cited articles, 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 cooccurrence 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. 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, \( P = .01 \)). 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 \( = 0.746–2.926, \)

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**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.

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

Author contributions

Data analysis: Zhipeng Zhao, Hongfu Zhao.
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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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