Observational Study

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Global research trends and hotspots on imaging of bladder cancer

A bibliometric and visual analysis from 1981 to 2023

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Abstract

There was currently no bibliometric analysis available regarding to bladder cancer (BCa) imaging. The aim of this study was to conduct a comprehensive bibliometric analysis of relevant literature on the imaging of BCa and elucidate global research hotspots and further trends in this field. All relevant literature on the imaging of BCa published between 1981 and 2023 were retrieved from the Web of Science Core Collection. VOSviewer, Bibliometrix, and Citespace were utilized for bibliometric analysis of publications, countries, authors, institutions, journals, references, and keywords. A total of 4462 articles were retrieved. The research in this field has been increasing consistently since 1981. The United States of America was the most productive country and most productive institutions were from it. Shariat SF was the most productive author with 36 articles and the author with the highest co-citations was Herr HW (472). Journal of Urology was the most productive journal and Frontiers in Oncology, Abdominal Radiology and Cancers exhibited heightened activity in recent years. A study by Siegel RL, published in CA-A Cancer Journal for Clinicians in 2019, had the highest number of co-citations. Further analysis of the keyword analysis and timeline view revealed that "radiomics," "deep learning," "multiparametric MRI," "VI-RADS," "muscle-invasive bladder cancer," "immunotherapy," and "long term outcome" were the most recent hotspots. In totally, in the period of 1981 to 2023 year, the USA occupies a critical position in the field of BCa imaging. It is anticipated that MRI-based imaging-reporting and data system and deep learning will be the research hotspots in the future.

Abbreviations: BCa = bladder cancer, CPP = citations of peer paper, CT = computed tomography, H-Index = Hirsch Index, MRI = magnetic resonance imaging, PET = positron emission tomography, UK = United Kingdom, USA = United States of America, VI-RADS = vesical imaging-reporting and data system, WOSCC = Web of Science Core Collection.

Keywords: bibliometric, bladder cancer, medical imaging

1. Introduction

Bladder cancer (BCa) is the most common genitourinary malignancy. It is the ninth most common cancer worldwide. With its constantly increasing mortality rate in recent years, BCa has received extensive research attention.[1,2] The treatment decision and prognosis of BCa are mainly determined by the local progress of tumors, particularly for the invasion depth.[3] Transurethral resection of bladder tumor is efficacious in the treatment of low-grade intermediate-risk non-muscle-invasive bladder cancer, whereas a combination of neoadjuvant chemotherapy with radical cystectomy is effective in treating high-risk non-muscle-invasive bladder cancer or muscle-invasive bladder cancer.[4] Additionally, muscle-invasive bladder cancer is associated with high rates of metastasis and mortality, suggesting that the stage of BCa is also related to patients' prognosis.[5] Therefore, early detection and precise pretreatment assessment of BCa are crucial for effective clinical treatment and patient prognosis.

Postoperative or transurethral bladder biopsy is the most reliable method in the diagnosis of BCa; however, the inevitable invasiveness restricts its clinical application in screening and follow-up of BCa. Noninvasive examinations in the clinic, such as urine cytology and urine-based tumor markers, are also unsatisfactory in sensitivity or specificity.[6–9] Medical

ZG and ZL contributed equally to this work.

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The datasets generated during and/or analyzed during the current study are publicly available.

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imaging examinations, such as ultrasound, computed tomography (CT), magnetic resonance imaging (MRI), positron emission tomography (PET), and X-ray, are therefore received extensive attention of researchers for their noninvasive, convenient, and repeatable properties. Due to its affordability and non-radiative natures, ultrasound is commonly employed for BCa screening to exclude risks or suspicious presentations.[10] For the detection of microtumors and pretreatment assessment, the methods with higher resolution, such as CT, MRI, and less frequent PET, are more suitable.[11] They enable the visualization of the correlation between tumors and the surrounding tissue, as well as the detection of metastatic lesions, performing well in the diagnosis, staging, and prediction of metastasis and prognosis of BCa.[12–14] Since studies related to the imaging of BCa have been increasing dramatically, efficiently and systematically ascertaining the current status of global research in this field remains challenging.

Bibliometrics is a statistical technique that can capture the evolution of research in a given field by drawing visualization maps based on public literature databases, such as the diseases, journals, sites, techniques and references.[15] In consideration of the aforementioned data, the present development status and future hot directions of the field in question can be deduced. This provides readers and researchers in the field with a rapid means of understanding the field.[16,17] Currently, it has been employed to many researches to investigate publication and hotspots in a certain field,[18–22] but there is still a lack of analysis focus on imaging of BCa.

The present study aims to analyze the studies related to the imaging of BCa published between 1981 and 2023 using bibliometrics and summarize the current research hotspots and future development trends.

2. Method

All data were obtained through literature retrieval based on the Canonical database. No medical institutions or patients were included, and thus ethical approval or informed consent was not applicable.

2.1. Source and search parameters

Web of Science Core Collection (WoSCC, Clarivate Analytics, London, UK) is a bibliometric database that features premium journals and articles in diverse fields.[23] It was the primary data source of this study due to its guarantee in the high-quantitative journals. All related literature was retrieved from all indexes of WoSCC database, including Social Sciences Citation Index, Arts and Humanities Citation Index, Conference Proceedings Citation Index-Science, Conference Proceedings Citation Index-Social Science and Humanities, Book Citation Index-Science, Book Citation Index Social Science & Humanities, Emerging Sources Citation Index, Current Chemical Reactions Expanded and Index Chemicus, at July 25, 2023.

Full records and cited references of articles were downloaded and saved in plain text format. Eligible publications included articles and reviews focusing on imaging of BCa published between January 1, 1981 and December 31, 2023. The searching query string is provided in the Appendix 1, Supplemental Digital Content, http://links.lww.com/MD/O561. A total of 5344 studies were retrieved from WOSCC. Among the literature retrieved in this study, English accounted for the most (95%) of all the documents. To ensure the retrieved documents could be managed and analyzed effectively by the software, documents written in English as article or review were therefore retained. After reviewing according to the flowchart shown in Figure 1, a total of 4462 studies related to the imaging of BCa were finally retrieved, encompassing 3692 articles and 637 reviews.

2.2. Data analysis and visualization

VOSviewer (version 1.6.19), Bibliometrix software (version 4.1.3), and Citespace (version 6.1.6, basic) were utilized for bibliometric analysis of publications, countries, authors, institutions, journals, references, and keywords. Microsoft Excel (version 2019) was used for designing charts based on publications. Detail of data processing and the use of software were shown in the Appendix 2, Supplemental Digital Content, http://links.lww.com/MD/O563. As the principal analysis tool, VOSviewer software was used for bibliographic coupling, co-occurrence, co-authorship, and co-citation analysis.[24] It can illustrate the timing of the appearance, and the relationship of these elements through the utilization of point and lines. Bibliographic coupling analysis was performed to assess the similarity degree between journals based on the quantity of co-cited references. Co-occurrence analysis for keywords and co-authorship analysis for authors and their respective countries were also conducted by calculating the frequency of articles in which they co-occurred, which reflected the correlation between different items. Furthermore, co-citation, indicating the frequency of 2 or more authors being cited simultaneously within other documents, was utilized to evaluate the impact of authors. This process was repeated for references. The results were displayed using visualization maps, in which the size of nodes indicated the frequency of various authors, journals, or keywords, and the thickness of lines represented the degree of association between items.

Bibliometrix software was utilized for publication analysis of countries and query core journals according to Bradford's law, which demonstrates the unbalanced distribution of articles.[25] CiteSpace was employed for the analysis of global publications, keyword citation burst, and timeline view of co-cited references. A burst refers to a sudden surge in the frequency of a specific item, which represents the frequency of a keyword in a given study. The burst period was determined according to the Kleinberg algorithm.[26] Keyword citation burst and timeline view analyses demonstrate the hotspots in a given period and the research progress in a field.

Other bibliometric indicators included count of documents, total citations, citations of peer paper (CPP), Hirsch Index (H-index), and impact factor (within 5 years average). H-index indicates the number of publications cited at least H times. It provided a comprehensive index to assess the productivity and quality of papers of authors or institutions.[27] CPP was used for a joint evaluation. The H-index and citations in this study were restricted to the field of imaging of BCa. In addition, Price's law was employed to assess global productivity find identify the core authors who published on imaging of BCa.[28] Core authors are defined as the distinguished authors whose publications account for half of total publications in a field. Core authors were identified utilizing the following formula:

$$m = 0.749 \quad \times \quad \sqrt{N_{max}}$$

In the formula "m" represents the minimum publications required for core authors and "N_{max}" represents the highest number of publications by a single author.

3. Results

3.1. Analysis of global trend of publications

A total of 4462 studies were finally included in the present study. As shown in Figure 2, there was a consistent and significant growth in the publications since 1981, especially in the last 5 years. After exponential adjustment based on the yearly publications, a coefficient of determination R^2 was 0.951, and a linear adjustment attained an R^2 of 0.880. The results of mathematical adjustment indicated that the growth trend of publications in this field aligned more closely with the exponential adjustment, which was consistent with the postulates of Price's law.

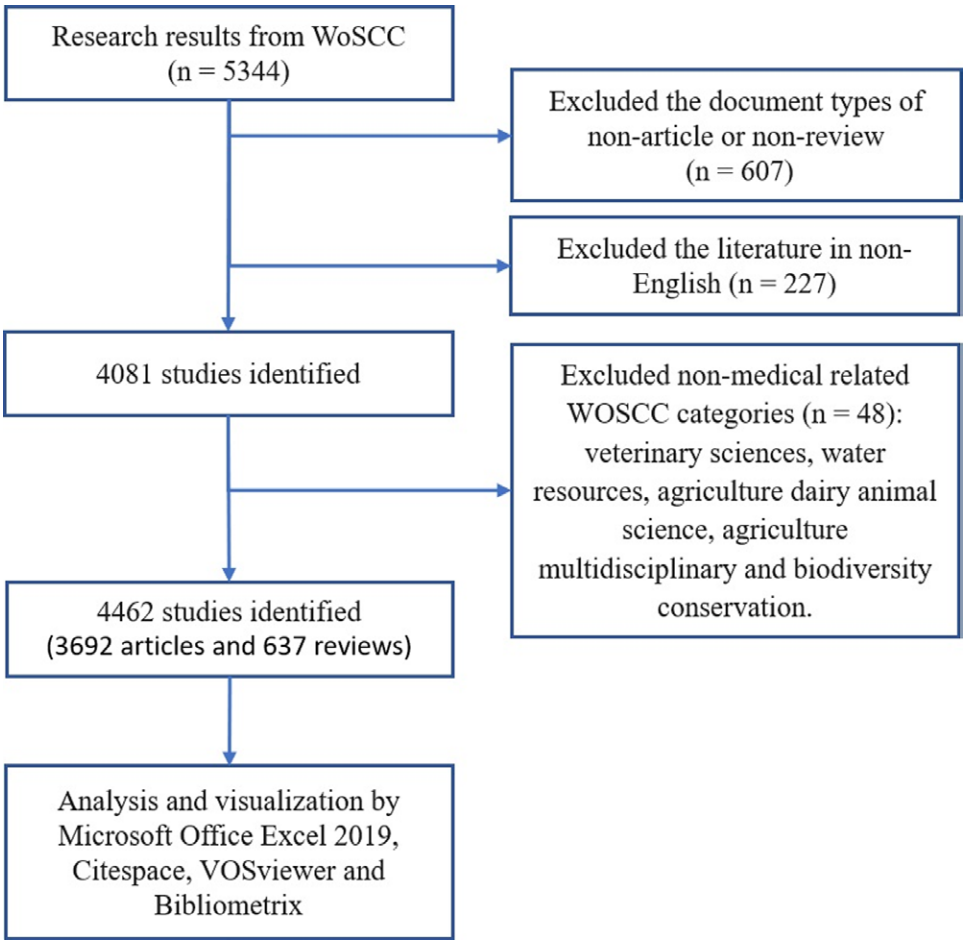

Figure 1. Flowchart of search strategy.

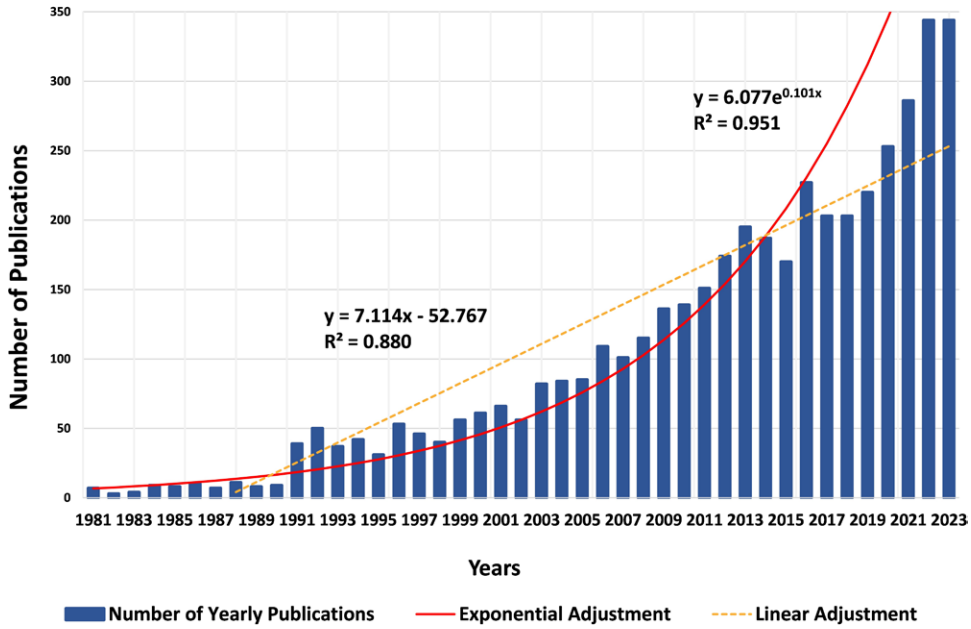

Figure 2. Global trend of publications on the imaging of BCa. The exponential adjustment and linear adjustment are based on the number of yearly publications from 1981 to 2023.

3.2. Analysis of countries

In total, 94 countries have contributed to the identified academic publications regarding to the imaging of BCa. Figure 3A displays the geographical distribution of publications. It can be seen that the articles were mainly published by United States of America (USA) and China, jointly accounting for 55.69%

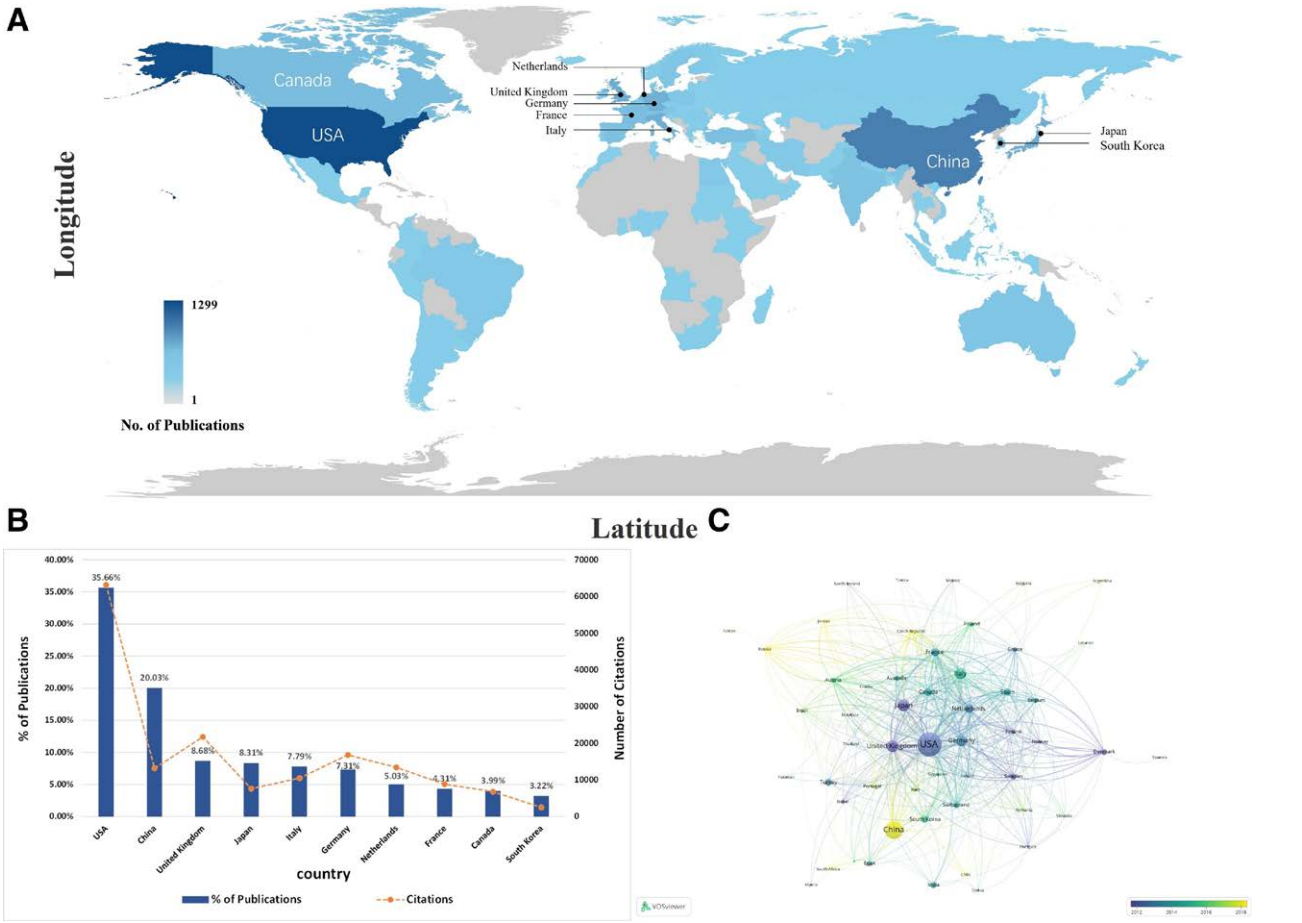

Figure 3. Geographical distribution of publications* (A), Bar chart of the top 10 countries based on the number of publications (B) and Overlay visualization map of countries with at least 5 documents** (C). (* The color depth represents the number of documents a country has published. **The thickness of lines represents the frequency of cooperation between countries. The color of an item represents the average published time of publications of a country. The closer the color was to the yellow, the closer the average publication time of papers from the country was to the present.)

of the total publications in this field. Figure 3B shows the proportion and citation of the top 10 countries with the highest production. Results illustrated that the countries following USA (32.06%) and China (18.97%) were United Kingdom (UK, 8.68%), Japan (8.31%), and Italy (7.79%), in that order. Furthermore, USA was ranked first in terms of citations, while China was ranked fourth. Co-authorship analysis for countries (Fig. 3C) revealed that 53 countries have published at least 5 articles. The top 5 countries with the highest frequency of inter-countries cooperation were USA, German, UK, Italy, and Netherlands, in this order. Additionally, China only recently began to concentrate on this field, because the majority of publications were published within the last 5 years.

3.3. Analysis of institutions

A total of 4288 institutions published studies on the imaging of BCa. The top 10 institutions with the highest number of publications are presented in Table 1, of which 9 were from the USA. The top 3 institutions were the University of Texas System (n = 179), Harvard University (n = 149), and the University of Texas MD Anderson Cancer Center (n = 116) respectively. The H-index of these institutions was > 20. The University of Texas System had the highest H-index (H = 48). It is noteworthy that despite bein11g ranked ninth in the productivity and H-index, Cornell university had the highest CPP (n = 71.53).

The mismatch between the number of publications and citations in the analysis of countries and institutions prompted us to further analyze the differences in intra-country institutional cooperation between USA and China. Figure 4 showed that the USA has a greater number of highly productive institutions than China. China has a paucity of intra-country institutional cooperation. There was a robust and collaborative relationship between institutions within the USA.

3.4. Analysis of authors and co-cited authors

A total of 23,186 authors published articles related to the imaging of BCa as first author or other related authors. Table 2 shows the top 10 most productive authors and the top 10 co-cited authors with the highest citations. Most of the authors and co-cited authors were from the USA. Shariat SF was the most productive author with 36 papers and had the highest H-index. The author with the highest CPP was Witjes JA, who was only ranked ninth in publications. The top 3 co-cited authors were Herr HW, Witjes JA, and Babjuk M, respectively. Based on Price's law, core authors in this field were those who published at least 5 related articles. There were 389 core authors, with a total of 2928 papers, accounting for 65.62% of the total publications. As shown in Figure 5, Shariat SF, Kamat AM, and Panebianco V, et al extensively collaborated with other authors. Despite having high productivity, Liu Y and Fujii Y, et al lacked associations with other authors and ranked outside the top 10 in co-citations.

3.5. Analysis of journals

All papers were published in 1081 journals. According to Bradford's law, the journals were divided into 3 zones with

Table 1

Top 15 most productive institutions.

Institutions	Country	Count	Citations	CPP	H-index
University of Texas System	USA	179	7855	43.88	48
Harvard University	USA	149	7845	52.65	43
University of California System	USA	116	4532	39.07	40
University of Texas MD (UTMD) Anderson Cancer Center	USA	114	5988	52.53	40
National Institutes of Health (NIH)–USA	USA	100	8249	82.49	39
University of London	UK	99	6431	64.96	38
Harvard Medical School	USA	93	5522	59.38	34
Memorial Sloan Kettering Cancer Center	USA	89	5310	59.66	31
Johns Hopkins University	USA	80	2762	34.53	30
Cornell university	USA	64	4578	71.53	25

CPP = citation of per paper, USA = United States of America, UK = United Kingdom.

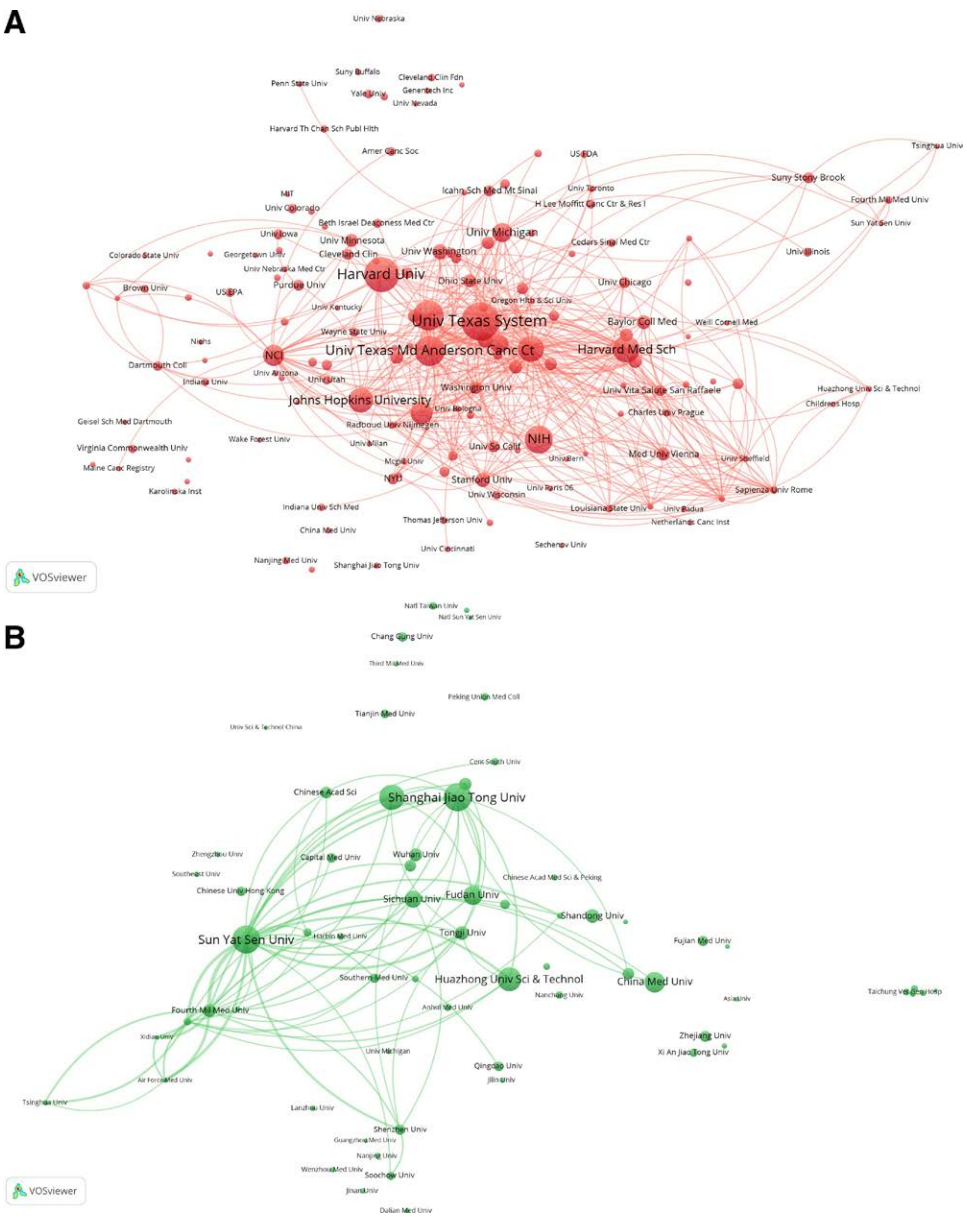

Figure 4. Co-occurrence map of intra-country institutions from USA (A) and China (B) respectively*. (* The size of the circle is determined by the publications of an institution and the thickness of lines shows the frequency of cooperation between 2 institutions.)

similar counts of publications, namely zone 1, zone 2, and zone 3, with 30, 144, and 906 journals, respectively (Table 3). The ratio of Bradford's multiplier was 1: 4.8: 30.2, based on Bradford's law. Zone 1 was the core area with 1345 publications. As shown in Figure 6, the most productive journal in this zone was Journal of Urology, with 148 papers, and the least

Table 2

Top 15 most productive authors and most frequently co-cited authors.

Author	Country	Count	Citations	CPP	H-index	Co-cited author	Country	Citations	H-index
Shariat SF	USA	36	1702	47.18	19	Herr HW	USA	472	7
Kamat AM	USA	30	980	31.67	14	Witjes JA	Netherland	434	23
Panebianco V	Italy	25	1043	36.00	13	Babjuk M	Prague	411	3
van Rhijn BWG	Netherland	22	784	34.04	16	Panebianco, V	USA	333	14
Lotan Y	USA	21	2443	114.60	15	Stein JP	USA	333	0
Black PC	Canada	20	562	28.94	13	Siegel RL	Spain	328	0
Liu Y	China	20	485	23.72	13	Powles, T	Italy	322	7
Lu HB	China	19	520	25.67	11	Bellmunt J	USA	320	8
Witjes JA	Netherland	19	2941	150.61	17	Jemal, A	USA	304	4
Fujii, Y	Japan	17	602	33.41	11	Shariat SF	Japan	303	21

CPP = citation of per paper, USA = United States of America, UK = United Kingdom.

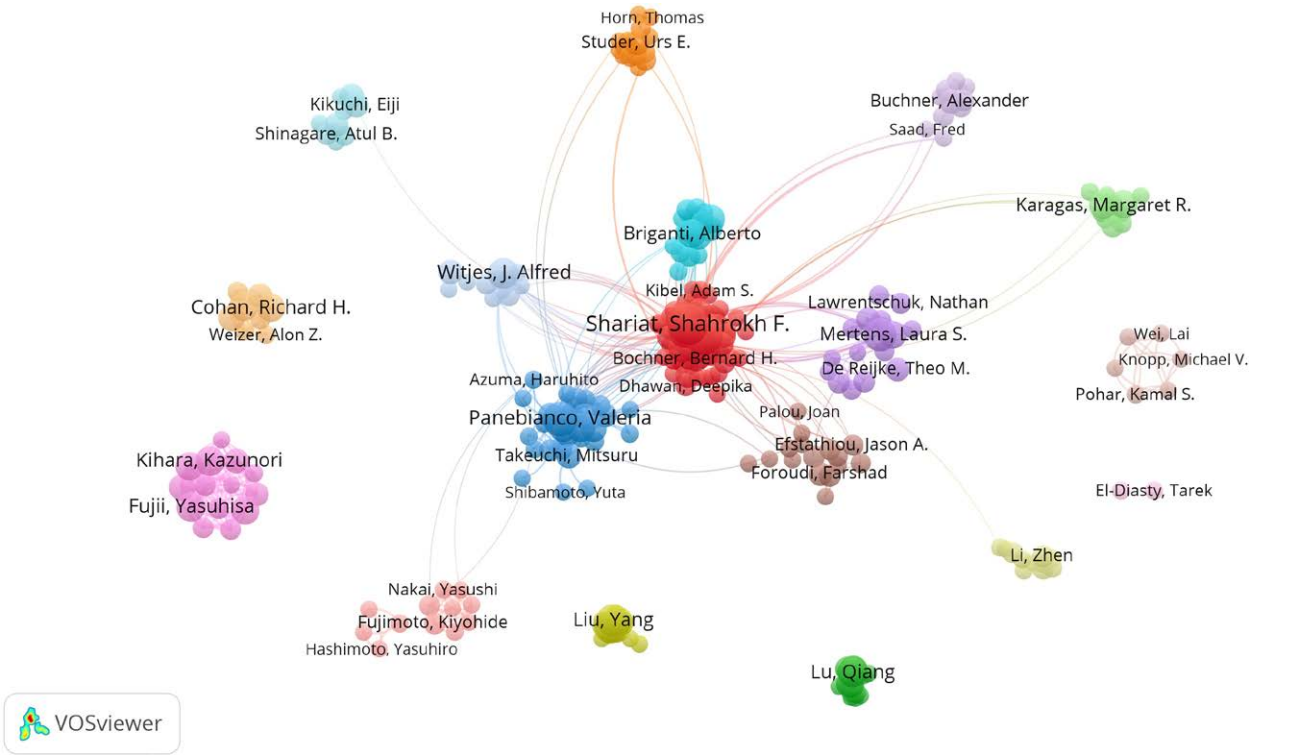

Figure 5. Co-authorship network visualization map of core authors with at least 5 papers*. (* The thickness of lines represents the frequency of 2 authors co-occurring in a paper and the size of the node represents their publication count.)

productive was American Journal of Roentgenology, with 56 papers. Furthermore, Frontiers in Oncology, Abdominal Radiology and Cancers exhibited heightened activity in recent years, in which major papers were published in the last 3 years. The top 10 most productive journals are displayed in Table 4, of which most were classified as Q1 by the Journal Citation Reports standard in 2022. Among these journals European Urology ranked first and Urology ranked last with an impact factor of 19.9 and 2.2 respectively. The H-index of Urology was significantly lower than that of Journal of Urology and European Urology, indicating the disparity between the quantity and quality of publications also exists within the journals.

3.6. Analysis of co-cited references

Analysis of co-cited references can help to identify highly influential articles. Table 5 displays the top 10 publications with the highest co-citations on the imaging of BCa, among which 6 are articles and 4 are reviews. Among them, Stein JP[29] et al was ranked first with 206 co-citations, and Siegel RL et al was ranked second with 193 co-citations.[30] The study by Takeuchi M et al investigated the effectiveness of diffusion-weighted imaging in determining T-stage of BCa and was ranked third.[31] Furthermore, 5 of the top 10 publications were published in European urology, which meets the result of the analysis of journals.

Table 3

Distribution of the journals in Bradford's zones.

Zone	No. of journal	% of journals	No. of documents	% of documents	Bradford multiplier
Core	30	2.78%	1499	33.59%	1
2	144	13.33%	1494	33.48%	4.8
3	906	83.89%	1469	32.92%	30.2
Total	1080	100%	4462	100%	

Bradford multiplier = No. of journals/33.

3.7. Analysis of keywords

There were 13,461 keywords in this field, and 608 keywords with a frequency of at least 10 times were finally included after removing 6 topic-related keywords, including "bladder cancer," "cancer," "urothelial carcinoma," "bladder," "tumor," and "bladder neoplasms." The top 10 keywords with the highest frequency were CT (467), radical cystectomy (389), MRI (348), diagnosis (348), prostate cancer (317), radiotherapy (277), risk (267), expression (259), chemotherapy (250), and survival (234) respectively (Fig. 7A). The overlay visualization map (Fig. 7B) clearly displays several keywords in yellow that have frequently appeared in recent years, represented by "Multiparametric MRI," "Radiomics," "Deep learning," "Muscle-invasive bladder cancer," "Data system," and "Tumor microenvironment."

The top 25 keywords with the strongest citation bursts are displayed in Figure 7C. During the early years before 2011, "conformal radiotherapy," "cigarette smoking," "radical radiotherapy," "virtual cystoscopy," "fdg pet," and "tumor detection" were the most cited keywords related to research on imaging of BCa. Divided by "adaptive radiotherapy" with a cited strength of 17.45, "muscle-invasive bladder cancer," "deep learning," "long term outcome," "multiparametric MRI" were frequently cited keywords in recent years. The time variation of co-cited references is depicted in Figure 7D. The earliest cluster was "dna repair" and "virtual endoscopy." The clusters continued to present were "vi-rads," "immunotherapy," and "radiomics."

4. Discussion

The present study explored research progress, current hotspots, and future trends in the imaging of BCa using VOSviewer, CiteSpace, and Bibliometrix based on the bibliometric method. A total of 3692 articles and 637 reviews related to the imaging of BCa have been published since 1981 and there has been an exponential growth in yearly publications in this field, and this trend has not reached saturation. MRI-related medical imaging methods

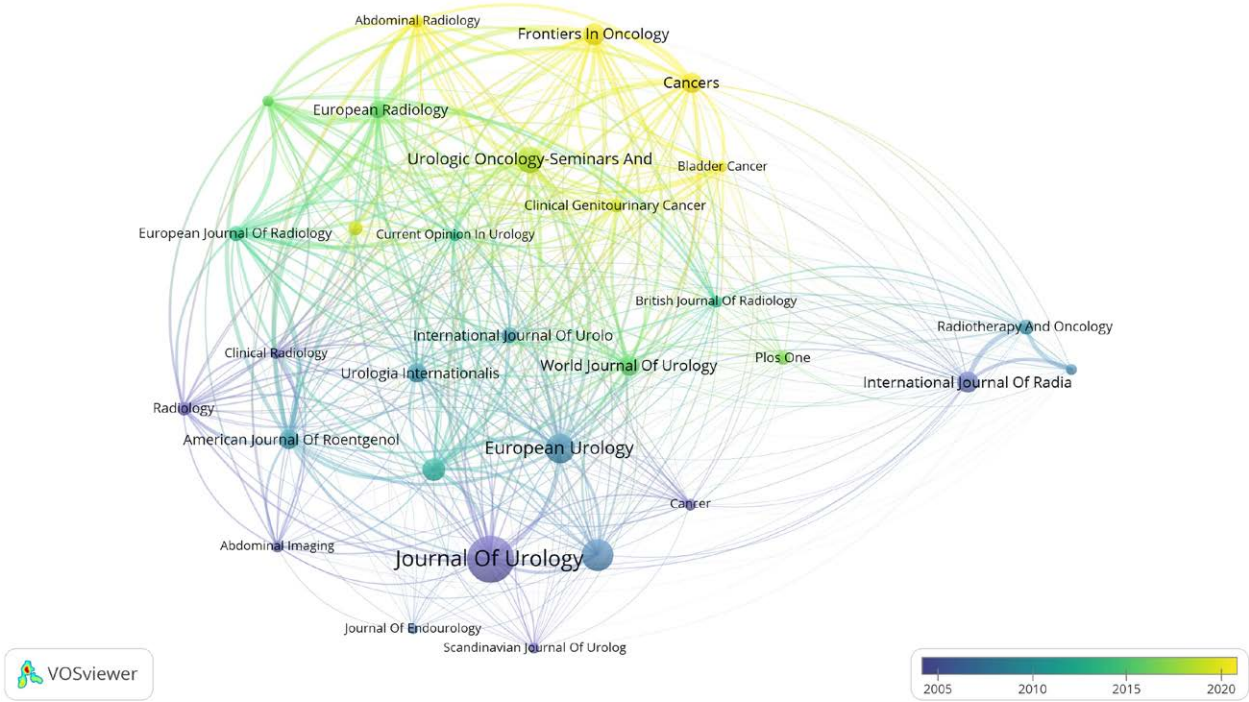

Figure 6. Overlay visualization map of institutions in the core of Bradford's zones*. (*The thickness of lines represents the frequency of the same references cited by 2 journals. The color of an item represents the average published time of publications of a journal. The closer the color was to the yellow, the closer the average publication time of papers from the institution was to the present. The size of the circle is determined by the number of publications of the item.)

Table 4

Top 10 most productive journals.

Journal	Count	Citations	IF	JCR (2022)	H-index
Journal of Urology	148	7620	6.2	Q1	51
Urology	97	2434	2.2	Q3	28
European Urology	89	9218	19.9	Q1	47
Urologic Oncology-Seminars and Original Investigations	76	1100	4.5	Q3	20
BJU International	67	2267	2.8	Q1	29
Frontiers in Oncology	63	370	5.2	Q2	11
International Journal of Radiation Oncology Biology Physics	62	3361	3.5	Q1	37
World Journal of Urology	59	983	6.6	Q2	18
Cancers	58	304	4.2	Q1	10
American Journal of Roentgenology	56	2352	5.6	Q1	31

IF = impact factor, JCR (2022) = Journal Citation ReportsTM 2022.

Table 5

Top 10 most co-cited references.

Title	Co-citations	First-author	Journal	Article type	Year
Radical cystectomy in the treatment of invasive bladder cancer: long-term results in 1054 patients	206	Stein JP	J Clin Oncol	Article	2001
Cancer statistics, 2019	193	Siegel RL	Ca-Cancer J Clin	Article	2019
Urinary bladder cancer: diffusion-weighted MR imaging--accuracy for diagnosing T stage and estimating histologic grade	167	Takeuchi M	Radiology	Article	2009
Multiparametric Magnetic Resonance Imaging for Bladder Cancer: Development of VI-RADS (Vesical Imaging-Reporting And Data System)	167	Panebianco V	Eur Urol	Review	2018
Global cancer statistics 2018: GLOBOCAN estimates of incidence and mortality worldwide for 36 cancers in 185 countries	137	Jemal A	Ca-Cancer J Clin	Review	2011
Neoadjuvant chemotherapy plus cystectomy compared with cystectomy alone for locally advanced bladder cancer	133	Grossman HB	New Engl J Med	Article	2003
European Association of Urology Guidelines on Muscle-invasive and Metastatic Bladder Cancer: Summary of the 2020 Guidelines	121	Witjes Ja	Eur Urol	Article	2021
Bladder Cancer Incidence and Mortality: A Global Overview and Recent Trends	120	Antoni S	Eur Urol	Review	2017
EAU Guidelines on Non-Muscle-invasive Urothelial Carcinoma of the Bladder: Update 2016	118	Babjuk M	Eur Urol	Review	2017
Predicting recurrence and progression in individual patients with stage Ta T1 bladder cancer using EORTC risk tables: a combined analysis of 2596 patients from 7 EORTC trials	113	Sylvester RJ	Eur Urol	Article	2006

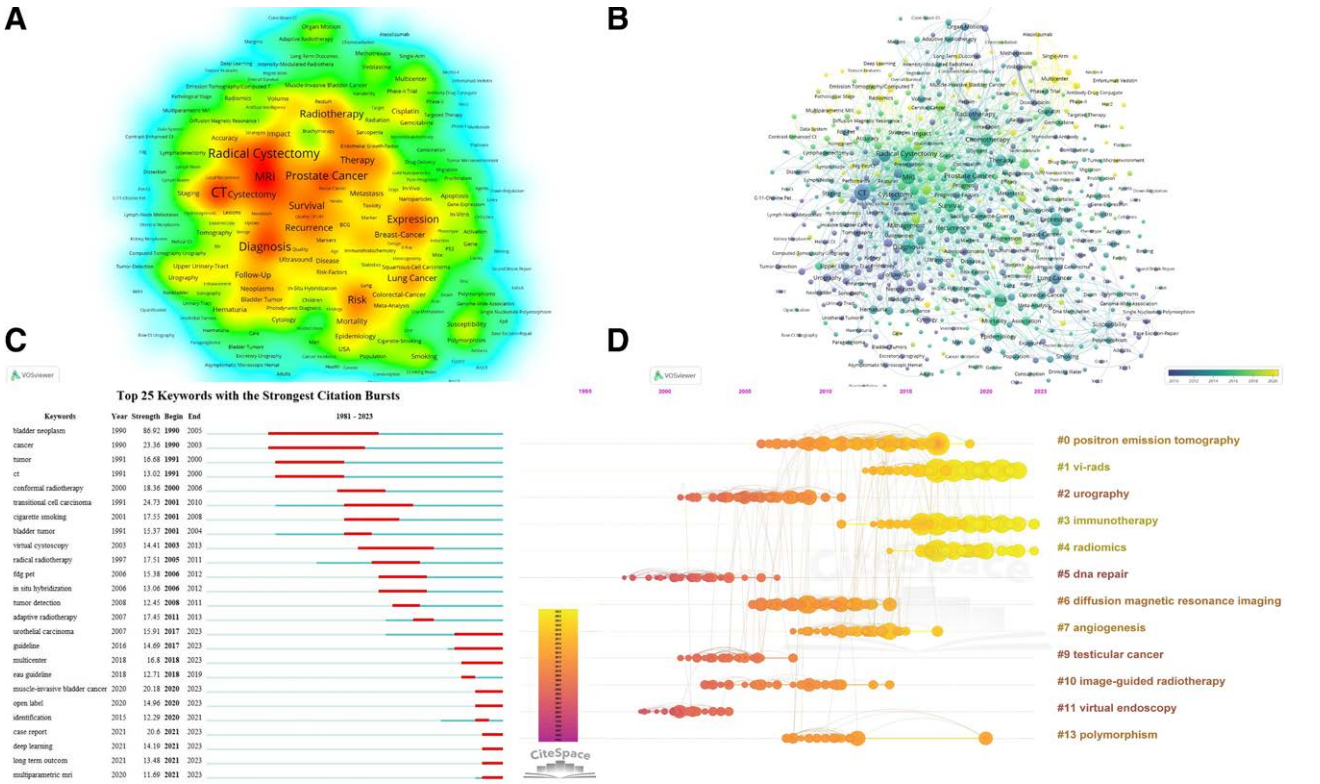

Figure 7. The heat map of keywords* (A) and the overlay visualization map of keywords with a frequency of no <10 times** (B). The top 25 keywords with the strongest citations bursts of keywords*** (C). Timeline view of co-cited references on imaging of BCa****(D). (*Each color represents the frequency of a keyword; warm red indicates the hot areas, and cold blue indicates the cold areas. The size of the area and the font size are determined by the frequency of keyword. **The thickness of lines shows the frequency of 2 keywords co-occurring in a paper. The color in the overlay map representing the average occurrence time of the keyword. The closer the color was to the yellow, the closer the appearance time of keyword was to the present. The size of the circle is determined by the frequency of keyword. ***The blue line indicates the time interval, while the burst period is indicated as the red segment on the blue timeline. Year represents the time at which a keyword occurred and the strength indicates the citation strength during the burst period. The strength represents the frequence with which it was cited during the burst period. ****The time evolution is presented with different colored lines, and the nodes on the lines indicate the references cited. The brighter they are, the more recently they occurred.)

and artificial intelligence are the current hotspots and will remain so in the future.

The USA occupies a critical position in this field, demonstrated by the highest number of publications and citations compared with other countries. China was the second-largest publisher of articles. The network of countries demonstrated that the publications of China was mainly concentrated in recent years. It may be attributable to a combination of

factors, including the advancement of medical care in China in recent years, the increasing incidence of BCa, and the growing emphasis on scientific research.[32,33] However, it is worth noting that although China ranked second in the number of publications, its total citations were unsatisfactory, which indicated its deficiency in the quality of articles. It could be attributed to the fact that the cooperation between and within country of China was significantly lower than USA. This was supported by the findings of the analysis of the cooperation between countries and institutions. Consequently, China should pursue the establishment of stronger institutional ties within and between countries, with the objective of enhancing its academic influence.

Publications of core authors accounted for over 50% of the total literature in this field. According to Price's law,[28] research in this field has established a stable group of authors. Scholars can therefore receive consistent feedback by focusing on these core authors. In the core journals, the Journal of Urology and European Urology are the key journals in this field, ranking first in productivity and citations respectively. In addition, "Frontiers in Oncology," "Abdominal Radiology," and "Cancers" – with a surge in the number of publications in the past 3 years – have shown their potential for further progress in the future. However, based on most of the analyses in the present study, it is noteworthy that the quantity and quality of papers should not necessarily be equated. The author visualization map suggests that the majority of these authors have engaged in less cooperation, or even exhibited an absence of extensive collaborative studies. Scholars should also strengthen cooperation with others to improve the quality of their papers. The most co-cited article was published by Stein JP et al,[29] which mainly focused on the efficacy of radical cystectomy in the treatment of invasive BCa. This study provided valuable insights into research on imaging of BCa. Moreover, it is worth noting that 2 out of the top 10 co-cited articles were centered around imaging, both of which were MRI-related studies.[31,34]

The present study demonstrated that the research on the imaging of BCa could be divided into 2 periods. The first period, the years before 2011, can be further subdivided into 3 distinct periods, as determined by imaging techniques. In the early stage of first period, CT was the most popular method in this field, with CT-based techniques such as contrast-enhanced CT, CT urography also exhibiting good performance in the detection of BCa.[35] Since then, more noninvasive CT-based imaging techniques have been explored, particularly virtual cystoscopy, which was initially introduced by Vining and coworkers in 1995, peak of interest in 2003, and until 2013. Based on CT image reformatting in various ways to present 3D images of the urinary bladder, virtual cystoscopy can acquire images correlating well with standard cystoscopy.[36] Narumi et al found that virtual cystoscopy identified 94% of tumors >1 cm in diameter.[37] However, the radiation and handicap in detecting tumors <1 cm limited the performance of virtual cystoscopy in BCa screening and early diagnosis.[38] In the later stage of the first period, PET has received considerable attention in the field of BCa research. PET had a proficient performance when evaluating recurrence and metastasis of tumors in various areas of body by detecting changes in tissue metabolic activity.[39,40] Previous studies suggested that PET also could be used to assess the lymphatic metastasis in BCa,[41] but its high cost and uncertainty of diagnostic value restricted its clinical application. Totally, in the first period, the pretreatment assessment of BCa was merely focused on lesions detection, regardless of CT or PET. With the rise in tumor treatment options and the growing focus on prognosis, researchers were no longer content with lesions detection.

During the second period from 2011 to date, scholars focused great efforts on a more comprehensive evaluation before treatment decisions according to various personal characteristics. Takeuchi et al found that the combined model of T2WI, diffusion-weighted imaging, and dynamic contrast enhancement presented a satisfactory performance with a sensitivity of 90% and a specificity of 88% for evaluating the T stages of BCa.[31] Thoeny et al[42] and Zhang et al[43] noted that various sequences of MRI also performed well in the assessment of aggressiveness and N-stages in BCa. These studies demonstrated the irreplaceable value of MRI in this field. Recently, a vesical imaging-reporting and data system (VI-RADS) was developed based on 3 sequences with a stable diagnostic value, including T2WI, diffusion-weighted imaging, and dynamic contrast enhancement-MRI. Similar to the prostate imaging-reporting and data system, the utilization of VI-RADS has significantly promoted the accuracy in staging and grading of BCa by a standard reporting format.[44] However, the current sensitivity of MRI in the evaluation of lymphatic metastasis of BCa is still unsatisfactory.[45] There was a need for more accurate methods of pretreatment assessment of BCa.

Keywords analysis suggest that "Multiparametric MRI," "radiomics," "deep learning," "Muscle-invasive bladder cancer," "data system," and "long term outcome" were the keywords that had received considerable attention recently. Combining with the timeline view, we can conclude that the following 2 aspects might be the focus of future research on the imaging of BCa. The first aspect concerns the construction of an MRI-based imaging-reporting and data system, such as a VI-RADS.[44] The other aspect is the exploration of combining images with deep learning and radiomics, which are the branches of artificial intelligence. Compared with radiomics, it can easily and automatically acquire an amount of available data for the segmentation and prediction of lesions by artificial neural networks.[46,47] Tumor segmentation is a crucial area of research in this field. Based on the U-Net – a widely acknowledged model with defined effectiveness – many scholars have constructed automated segmentation models to distribute tumors and bladder walls and generated significant dice similarity coefficient values.[48,49] Compared with the highest dice similarity coefficient value from the model based on efficient convex optimization of coupled surfaces before deep learning, the deep learning-based model exhibited greater performance for tumor and bladder wall segmentation (87.3% vs 90% in dice similarity coefficient value).[50,51] Additionally, deep learning has achieved good results in image optimization, diagnosis, staging, and long term outcoming of BCa.[52,53] As another branch of artificial intelligence, radiomics is often applied in conjunction with machine learning. Numerous studies have explored the incorporation of machine learning in the preoperative evaluation of BCa. Wu et al[54] developed an MRI-based radiomics model, which yielded an area under the curve of 0.89 in the prediction of lymphatic metastasis in BCa. Xu et al[55] constructed an MRI-based machine learning model to forecast the recurrence risk of BCa after surgery in 2 years, which yielded an area under the curve of 0.838. Additionally, other studies suggested that the introduction of radiomics could promote the ability of gene-phenotype prediction in BCa and enhance the efficacy of immunotherapy and neoadjuvant chemotherapy.[56,57]

5. Limitation

There are some limitations in our study. Firstly, this study only included literature originally published in English from the WoSCC database, which resulted in the omission of relevant studies published in other languages or databases, such as Pubmed and Scopus. Secondly, due to the timely cumulative number of citations, high-quality papers published in recent years may have not attained the ideal citations, which may lead to these documents might not be included in the high-value article cohort in the study. Consequently, it is more appropriate to assess the quality of recently published studies based on the overall impact of the publishing journal, institution and authors. Thirdly, the query string search covering all related publications

is preferable; thus, we expanded the terminology of imaging technology to the subsequence. However, still some related studies were ignored.

6. Conclusion

A stable core group of authors and journals has been established in this field, and by focusing on them, researchers can obtain cutting-edge research results more expeditiously. Research on imaging of BCa is currently dominated by the USA and its institutions, journals, and authors. It is anticipated that MRI-related medical imaging methods and artificial intelligence will be the future research hotspots in this field.

Author contributions

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