Review

Med Ultrason 2025, Vol. 27, no. 2, 217-226
DOI: 10.11152/mu-4443

Ultrasound for breast cancer detection: A bibliometric analysis of global trends between 2004 and 2024

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Abstract

With the advancement of computer technology and imaging equipment, ultrasound has emerged as a crucial tool in breast cancer diagnosis. To gain deeper insights into the research landscape of ultrasound in breast cancer diagnosis, this study employed bibliometric methods for a comprehensive analysis spanning from 2004 to 2024, analyzing 3523 articles from 2176 institutions in 82 countries/regions. Over this period, publications on ultrasound diagnosis of breast cancer showed a fluctuating growth trend from 2004 to 2024. Notably, China, Seoul National University and Kim EK emerged as leading contributors in ultrasound for breast cancer detection, with the most published and cited journals being *Ultrasound Med Biol* and *Radiology*. The research spots in this area included "breast lesion", "dense breast" and "breast-conserving surgery", while "machine learning", "ultrasonic imaging", "convolutional neural network", "case report", "pathological complete response", "deep learning", "artificial intelligence" and "classification" are anticipated to become future research frontiers. This groundbreaking bibliometric analysis and visualization of ultrasonic breast cancer diagnosis publications offer clinical medical professionals a reliable research focus and direction.

Keywords: breast cancer; ultrasound diagnosis; global trends; bibliometrics analysis

Introduction

Breast cancer is the leading cause of cancer-related deaths among women globally [1]. According to continuous data from GLOBOCAN, there were approximately 2.3 million new cases of breast cancer and 685,000 deaths from breast cancer globally in 2020. In China, both the age-standardized incidence rate and mortality rate have significantly increased from 2000 to 2012 [2]. Due to the lack of specific symptoms and signs in its early stages, breast cancer often progresses to a more advanced stage by the time of diagnosis, resulting in a poor overall prognosis. Therefore, early and accurate diagnosis is crucial for improving survival rates and enhancing the quality of life for breast cancer patients.

Ultrasound (US) diagnosis is a key imaging modality for breast cancer, utilizing high-frequency acoustic waves to scan breast tissue and generate images based on differences in echo signals. This technique helps clinicians identify breast lesions and provides essential information for the clinical diagnosis and treatment of breast cancer [3,4]. With advancements in US technology, such as improved resolution and diverse imaging modalities, the application of US in breast diagnosis continues to evolve. Innovations like three-dimensional US, elastography, and contrast-enhanced US have significantly enhanced the accuracy of breast cancer detection [5,6]. Over the past two decades, the volume of literature on breast cancer US diagnosis has expanded considerably [7,8]. However, there is a lack of systematic organization and analysis of these developments, and research hotspots are continually shifting. To address this gap, this study employs VOSviewer and CiteSpace software for

Received 30.08.2024 Accepted 23.09.2024
Med Ultrason
2025, Vol. 27, No 2, 217-226
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a bibliometric analysis of US in breast cancer detection from 2004 to 2024. By retrieving data from major databases, the study aims to collate, analyze, and visualize the information to identify research trends, hotspots, and key contributors, providing valuable insights and references for future research efforts.

Materials and methods

Data collection

The data for this study was obtained from the Web of Science (WOS) Core Collection database, renowned for its authoritative coverage of over 10,000 journals, making it a leading resource in bibliometric research. Our retrieval strategy combined subject-specific terms and free-text keywords, as detailed below: TS= ("Ultrasonography" OR "Diagnostic Ultrasound*" OR "Ultrasound*, Diagnostic" OR "Ultrasound Imaging" OR "Imaging*, Ultrasound" OR "Echotomography" OR "Ultrasonic Imaging" OR "Imaging, Ultrasonic" OR "Sonography, Medical" OR "Medical Sonography" OR "Ultrasonographic Imaging*" OR "Imaging*, Ultrasonographic" OR "Echography" OR "Diagnos*, Ultrasonic" OR "Ultrasonic Diagnos*" OR "Echotomography, Computer" OR "Computer Echotomography" OR "Tomography, Ultrasonic" OR "Ultrasonic Tomography") AND TS=('breast cancer*" OR "Breast Neoplasm*" OR "Breast Tumor*" OR "Mammary Cancer*" OR "Breast Malignant Neoplasm*" OR "Malignant Neoplasm of Breast" OR "Malignant Tumor of Breast" OR "Breast Malignant Tumor*" OR "Mammary Carcinoma*" OR "Breast Carcinoma").

Inclusion and exclusion criteria

The inclusion criteria for studies in the analysis were as follows: (1) the type of literature must be original papers or reviews; (2) the research topic must be related to the US diagnosis of breast cancer; (3) the literature must have been published between January 1st, 2004, and March 25th, 2024; (4) the language must be English. Exclusion criteria were as follows: (1) studies unrelated to US diagnosis of breast cancer; (2) duplicate publications; (3) conference abstracts, editorials, corrections, letters, news articles, book chapters or withdrawn documents, etc.

Literature screening

Firstly, relevant literature was retrieved from the WOSCC database according to the defined retrieval strategy. Next, the retrieved literature was screened based on the inclusion and exclusion criteria. This process was carried out independently by two researchers (YYS and XTS), followed by a cross-check. In cases of disagreement, the researchers discussed the differences and reached a consensus; if a consensus could not be achieved, the third author (LLX) was consulted.

Data analysis

The software tools used in this analysis include Microsoft Excel 2016, the bibliometrix package for R 4.3.1, VOSviewer v1.6.18, and CiteSpace 6.1.r3. Microsoft Excel 2016 is utilized for literature collation and the creation of corresponding tables. The bibliometrix package in R 4.3.1 is employed to count and visualize data related to publication year, country, institution, author, journal, and keywords. VOSviewer v1.6.18, a visual network map analysis software developed by Nees Jan van Eck and Ludo Waltman from Leiden University, is used to analyze collaboration networks among countries, institutions, journals, and authors. CiteSpace 6.1.r3, developed by Dr. Chen of Drexel University, is used for visualizing cooperation networks of countries, journals, and authors. It also performs temporal sequence analysis and emergence analysis of keywords. In CiteSpace, the following parameters are set: time slice from January 1, 2004, to March 25, 2024; term sources include title, abstract, author keywords, and keyword plus; node types are author, institution, country, and keyword; link strength is measured by cosine; and selection criteria include the top 50 nodes. In the network visualizations, nodes represent entities such as authors, countries, or institutions. Connections between nodes indicate collaborative relationships. Larger circles signify a higher number of published articles, while wider lines represent stronger relationships.

Results

Search results

First, a total of 4,855 articles were retrieved from the WoSCC database. Next, 675 papers, including conference abstracts, social materials, letters, news articles, and withdrawn manuscripts, were excluded. Additionally, 532 papers published before 2004 were removed, resulting in a remaining 3,648 papers. Subsequently, 4 duplicate articles, 9 articles unrelated to the research topic, and 112 articles in languages other than English were excluded. This process yielded a final set of 3,523 papers, as illustrated in figure 1. The final 3,523 documents were exported from WoSCC in TXT format.

Annual publication growth trend

The publication years of the 3,523 articles were analyzed, as illustrated in figure 2. From 2004 to 2022, the number of publications exhibited fluctuations but generally increased over time. However, starting in 2023, there was a noticeable decline in publication numbers, despite an overall upward trend. This indicates a growing interest among researchers in the field of US diagnosis for breast

cancer. In 2016, a peak was reached with 211 publications and 6,783 citations. This was followed by 159 papers published in 2012, which garnered 5,977 citations. The total number of citations for the literature included in this study was 76,059, with an average citation frequency of 21.59. Additionally, from 2004 to 2024, the H-index for this academic field was 111.

Distribution of countries/regions

A total of 82 countries/regions have engaged in research on US diagnosis of breast cancer. Table I presents detailed metrics for the top 10 countries in this field, including the total number of publications, total citations (GCS), citations specific to this field (LCS), average number of citations, average number of local citations, the number of papers co-authored with international researchers (MCP), the number of papers co-authored by researchers of the same nationality (SCP), and the international cooperation rate. Among these countries, China leads with the highest number of publications (NP=867, 28.01%), followed by the United States (NP=621, 20.06%), South Korea (NP=408, 13.18%), Japan (NP=333, 10.76%), and Turkey (NP=186, 6.01%). The United States also ranks highest in both total citations (GCS=21,695) and local citations (LCS=2,075), followed by China (GCS=11,092, LCS=1,594). The United States has the highest average number of citations per paper (34.94), followed by United Kingdom (30.58). The United Kingdom also leads in average local citations (3.48), followed closely by the United States (3.34). The highest national cooperation rate is observed in the United Kingdom (0.50), followed by Germany (0.45) and the Netherlands (0.40). Overall, while China has the largest volume of published papers, the quality of these publications appears to be comparatively lower and could benefit from improvement. Figure 3A depicts the top 10 countries/regions by publication volume, with China, the United States, South Korea, Japan, and Turkey at the forefront. Figure 3B illustrates the annual publication trends for these leading countries, indicating a steady increase in publications related to US diagnosis of breast cancer across all countries, with China showing consistent growth from 2004 to 2024. Figures 3C and 3D display the international collaboration network, revealing that the United States engages in the most frequent international collaborations. Notably, the United States and China have the highest frequency of cooperative efforts, and China, the United States, the United Kingdom, Italy, Germany, and France are the leading contributors in the field of US diagnosis of breast cancer.

Distribution of research institutions

A total of 2,176 research institutions have contributed to the study of US diagnosis of breast cancer. The institution with the highest number of papers is Seoul National University (NP=220), followed by Yonsei University (NP=157) and the Yonsei University Health System (NP=147). The University of Texas System received the highest number of citations (GCS=4,118), followed by the University of Toronto (GCS=2,171) and Unicancer, a French hospital network dedicated to cancer prevention (GCS=2,098), as shown in figure 4A. Figure 4b lists the annual number of papers published by the top 10 high-yielding institutions in the field of US breast cancer. It is observed that the University of Texas and Mayo Clinic have been consistently active in this field from 2004 to 2024, while Sun Yat-sen University increased its focus on this field starting in 2012. The citation relationships between institutions were analyzed using VOSviewer, as illustrated in Figure 4c. Only institutions with at least 10 publications were included in the analysis, resulting in a network analysis of 119 institutions. The top five insti-

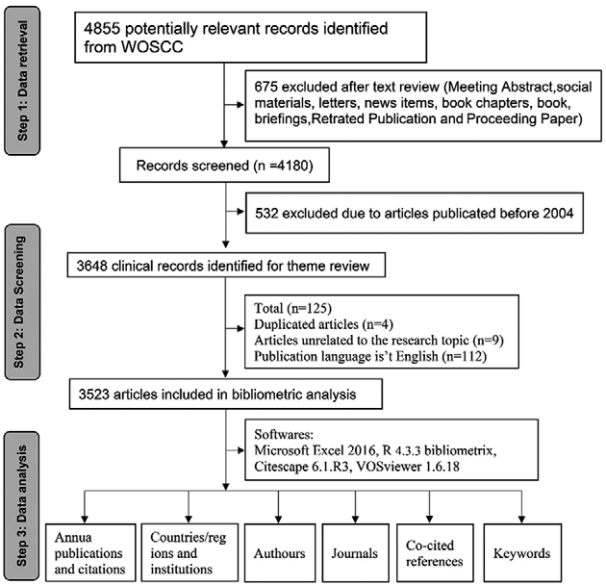


Fig 1. Flow chart for the bibliometric analysis.

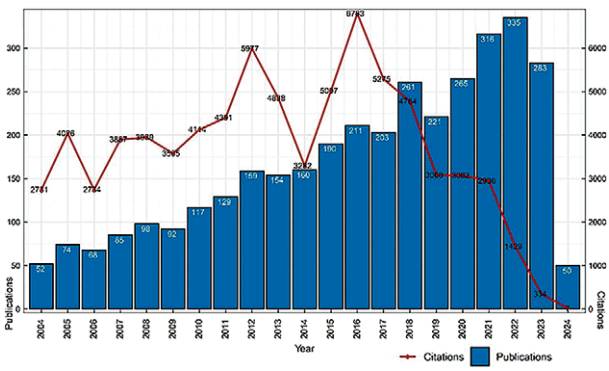


Fig 2. Trends in annual publication volume and annual citation counts.

Table I. Top 10 countries or regions contributing to clinical research on ultrasonic diagnosis of breast cancer

Rank	Country	Number of publications	Number of GCS	Number of LCS	Average Number of GCS	Average Number of LCS	SCP	MCP	MCP_Ratio
1	China	867	11092	1594	12.79	1.84	744	123	0.14
2	USA	621	21695	2075	34.94	3.34	414	207	0.33
3	Korea	408	6413	1144	15.72	2.80	378	30	0.07
4	Japan	333	4370	714	13.12	2.14	316	17	0.05
5	Turkey	186	1822	209	9.80	1.12	166	20	0.11
6	Italy	177	4660	494	26.33	2.79	129	48	0.27
7	UK	131	4006	456	30.58	3.48	65	66	0.50
8	Germany	128	2847	323	22.24	2.52	70	58	0.45
9	India	127	705	53	5.55	0.42	114	13	0.10
10	Netherlands	117	2892	421	24.72	3.60	70	47	0.40

GCS: global citation scores; LCS: local citation score; SCP: number of co-authored papers by authors of the same nationality; MCP: number of co-authored papers with authors from other countries.

tutions ranked by total link strength (TLS) are Shanghai Jiao Tong University (TLS=779), Yonsei University (TLS=726), Seoul National University (TLS=674), and Sun Yat-sen University (TLS=632).

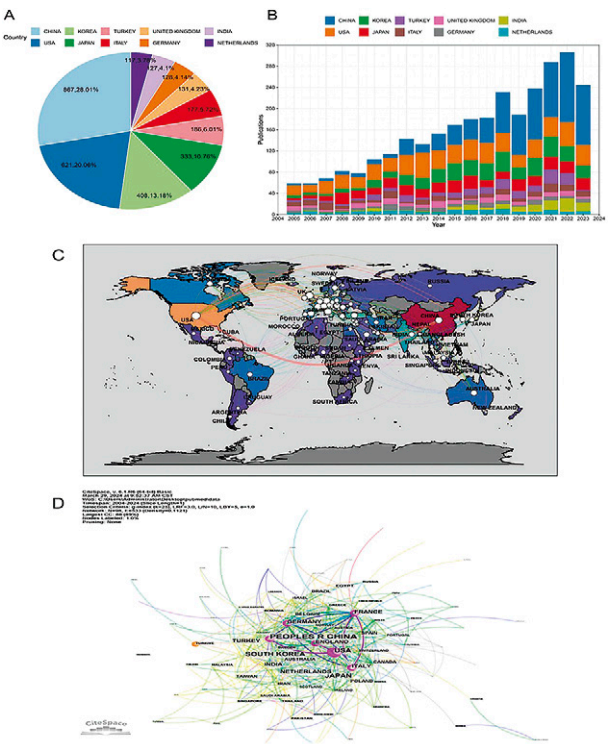


Fig 3. Distribution of different countries/regions to ultrasound diagnosis of breast cancer. (A) proportion of the top 10 countries in the research field of ultrasound diagnosis of breast cancer from 2004 to 2024. (B) annual publication trends of the top 10 countries in the field of ultrasound diagnosis of breast cancer over the past 20 years. (C) visual map of international collaboration among countries and regions, where gray indicates countries with no published articles. (D) network visualization of inter-state relationships in the field.

Authors and co-cited authors

Analysis of the 3,523 publications in this field revealed that a total of 15,215 authors have contributed to research on US diagnosis of breast cancer. Table II lists the top 10 most prolific authors in this area. Kim EK is the leading author with 61 publications (NC=61), 1,079 total citations (GCS=1,079), and 256 local citations (LCS=256), followed by Moon WK with 45 publications (NC=45), 1,243 total citations (GCS=1,243), and 239 local citations (LCS=239). Kim MJ ranks third with 43 publications (NC=43), 590 total citations (GCS=590), and 185 local citations (LCS=185). Chon has the highest average number of citations and local citations, with averages of 33.66 and 6.09, respectively. Moon WK leads

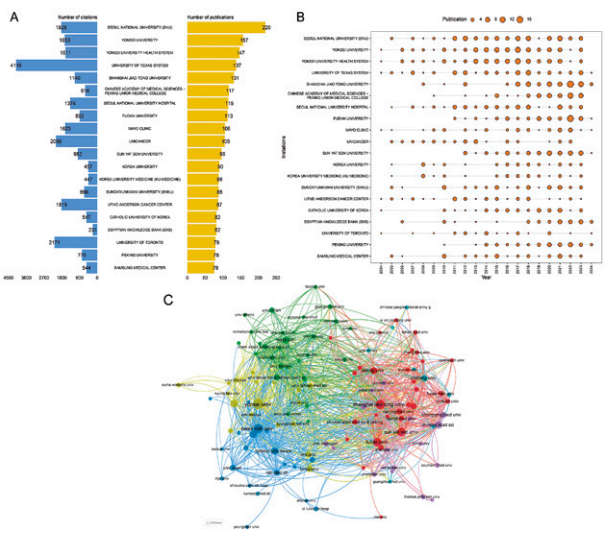


Fig 4. Distribution of different institutions in the field of ultrasound diagnosis of breast cancer. (A) the relationship between the organization and the number of documents and citations; (B) annual distribution trend of top 20 institutions; (C) network visualization of citation analysis of mechanism.

Table II. The top 10 most productive authors in ultrasonic diagnosis of breast cancer.

Rank	Author	Numbers of publications	H-index	G_index	M_index	GCS	LCS	Average Number of GCS	Average Number of LCS	PY_start
1	Kim EK	61	19	31	0.9	1079	256	17.69	4.20	2004
2	Moon WK	45	20	34	1	1243	239	27.62	5.31	2005
3	Kim MJ	43	12	23	0.67	590	185	13.72	4.30	2007
4	Moon HJ	35	10	21	0.56	494	156	14.11	4.46	2007
5	Wang Y	35	14	24	0.82	606	111	17.31	3.17	2008
6	Chang JM	33	15	25	1	678	146	20.55	4.42	2010
7	Kim SH	33	12	21	0.8	506	105	15.33	3.18	2010
8	Li J	33	11	20	0.61	457	60	13.85	1.82	2007
9	Cho N	32	17	32	1.06	1077	195	33.66	6.09	2009
10	Yoon JH	31	9	14	0.64	237	64	7.65	2.06	2011

GCS: global citation scores; LCS: local citation score

in both the H-index and G-index, achieving values of 20 and 34, respectively. For the VOSviewer joint analysis, a minimum threshold of 10 publications per author was set, resulting in the selection of 57 authors, as depicted in figure 5A. The authors were classified into six distinct clusters, with the red cluster (comprising 17 authors) representing the largest co-author network. Author citation analysis using VOSviewer is shown in figure 5B. Overlay visualization indicates that Tozaki M and Song BJ are the most closely related authors in early research, Chang JM is the most influential author in the mid-term, and Chang C, Zhang L, and Wang Y are the emerging authors in recent years. The top four authors based on total link strength (TLS) are Moon WK (TLS=364), Kim EK (TLS=362), Kim MJ (TLS=321), and Cho N (TLS=305).

Journals and co-cited journals

An analysis of 3,523 published articles in this field, spanning 876 journals, revealed that the top 30 journals – considered core journals – accounted for 1,164 articles, representing 33.04% of the total, as shown in figure 6A. Figure 6B presents the analysis of both the number of published papers and citation frequency for these core journals. The journal Ultrasound in Medicine and Biology published the highest number of papers (n=97), followed by Breast Cancer (n=70) and European Radiology (n=62). In terms of citations, Radiology leads with the highest number of total citations (GCS=2,144) and local citations (LCS=585), followed by Ultrasound in Medicine and Biology (GCS=2,144, LCS=426) and Annals of Surgical Oncology (GCS=1,589, LCS=505). Figure 6C displays the co-citation analysis of journals using VOSviewer software. Only journals with at least 5 articles were included, resulting in a selection of 168 journals for analysis. The top four journals ranked by total link strength (TLS) are Ultrasound in Medicine and Biology (TLS=570), Radiology (TLS=543), Annals of Surgical Oncology (TLS=449), and European Radiology (TLS=428). Figure 6D shows the double map overlay

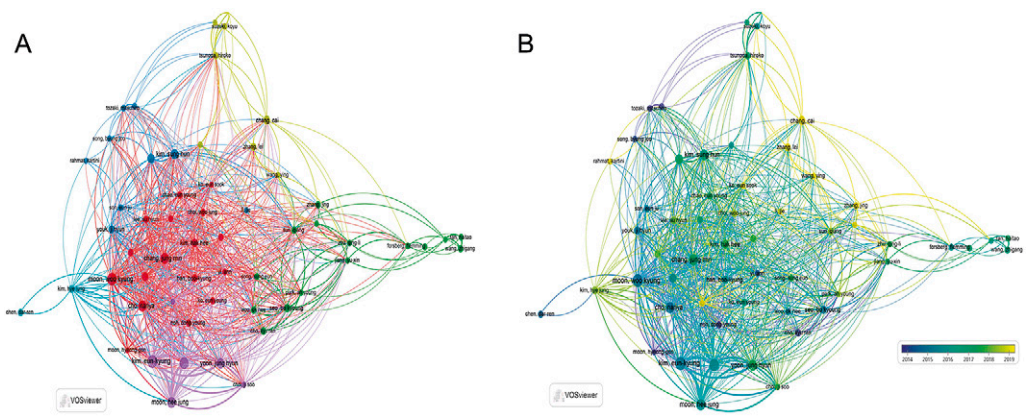


Fig 5. Distribution of authors in the field of ultrasound diagnosis of breast cancer. (A) analysis of global author collaboration network; (B) overlay visualization of author citation analysis based on vosviewer. The purple node represents the authors who participated in the early research in this field, while the Yellow node represents the authors who participated in the later research in this field.

analysis of journals. The results indicate that the cited journals in the field of US diagnosis of breast cancer are predominantly clustered in molecular biology/genetics and health/nursing/medicine, while they are frequently cited in medical/clinical journals.

Analysis of published literature

Analyzing the most-cited literature in this field helps identify the central research focuses and key studies, providing newcomers with a quick understanding of the primary research directions and areas of interest. Table III lists the top 10 most-cited studies in the field of US diagnosis of breast cancer. Notably, Siu AL's 2016 practice guideline, "Preventive Services Task Force Recommendation Statement," published in Annals of Internal Medicine, has the highest global citation score (GCS) of 1,256. This guideline indicates that there is no conclusive evidence supporting the benefit of US, magnetic resonance imaging (MRI), digital breast tomosynthesis (DBT), or other methods for auxiliary screening of breast cancer in women with dense breasts who have negative results on other screening mammograms. Figure 7A presents the analysis of the publication co-citation network, comprising 971 nodes, 4,094 edges, and a density of 0.0087. Figure 7B highlights the top 25 studies with significant citation bursts, ranging from 2004 to 2022. The most notable citation burst was for Al Dhabyani W's 2020 paper, "Dataset of breakaround images", published in Data Brief, with an intensity of 24.52. The citation volume for this paper surged from 2021 to 2024 and is expected to continue increasing. Following this, the study "Detection of Breast Cancer with Addition of Annual Screening Ultrasound or a Single Screening MRI to Mammography in Women with Elevated Breast Cancer Risk" (intensity 20.65) experienced a significant rise in citations from 2013 to 2017.

Keyword analysis

A comprehensive frequency analysis of keywords from 3,523 articles was conducted, revealing the top five most frequent keywords as "breast cancer," "ultrasound scanning," "tumor," "ultrasound," and "mammography" (fig 8A). All top 20 keywords, except for "MRI," have been consistently used from 2004 to 2024, with most showing a fluctuating upward trend over this period (fig 8B). VOSviewer software was employed for keyword co-occurrence analysis, identifying 9,008 keywords and selecting 158 with a co-occurrence frequency of at least 30 for detailed cluster analysis (fig 8C). The analysis revealed five distinct clusters: the Red Cluster, focusing on "ultrasound scanning," "biopsy," "cancer," "neoadjuvant chemotherapy," and "anatomy"; the Green Cluster, covering "ultrasound," "breast cancer," "treatment," "chemotherapy," and "contrast-enhanced ultrasound"; the Blue Cluster, involving "cancer," "diagnosis," "features," "damage," and "elastography"; the Yellow Cluster, centered on "breast X-ray irradiation," "women," "risk," and "magnetic resonance imaging"; and the Purple Cluster,

Table III. Top 10 most frequently cited references in ultrasound diagnosis of breast cancer.

Title	Year	Journal	LCS	GCS
Screening for Breast Cancer: U.S. Preventive Services Task Force Recommendation Statement	2016	Ann Intern Med	20	1256
Surveillance of BRCA1 and BRCA2 mutation carriers with magnetic resonance imaging, ultrasound, mammography, and clinical breast examination	2004	JAMA	33	856
Detection of breast cancer with addition of annual screening ultrasound or a single screening MRI to mammography in women with elevated breast cancer risk	2012	JAMA	109	775
Imaging biomarker roadmap for cancer studies	2017	Nat Rev Clin Oncol	0	665
Automated breast cancer detection and classification using ultrasound images: A survey	2010	Pattern recognition	48	480
Multifunctional nanoparticles for combining ultrasonic tumor imaging and targeted chemotherapy	2007	J Nat Cancer Inst	12	475
Automated Breast Ultrasound Lesions Detection Using Convolutional Neural Networks	2018	IEEE J Biomed Health Inform	55	466
Controlled and targeted tumor chemotherapy by ultrasound-activated nanoemulsions/microbubbles	2009	J Control Release	7	457
Breast cancer	2005	Lancet	4	434
Role of sonography in the diagnosis of axillary lymph node metastases in breast cancer: a systematic review	2006	AJR Am J Roentgenol	132	365

GCS: global citation scores; LCS: local citation score

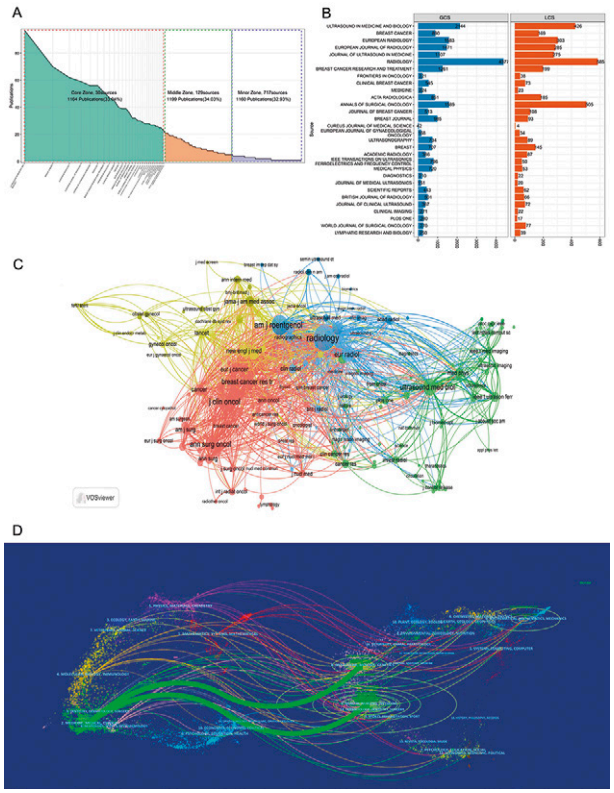


Fig 6. Publication and citation analysis of Journals in the field of ultrasound diagnosis of breast cancer. (A) the relationship between different journals and the number of papers published; (B) citations and local citations of core journals; (C) network visualization of journal co-citation analysis; (D) double map overlay analysis of journals, with the left side depicting the types of journals cited in the field of ultrasound diagnosis of breast cancer and the right side showing the types of journals citing these studies.

which includes "breast cancer," "prognosis," "diagnosis," "Tamoxifen," and "West Africa." Additionally, a burst analysis of keywords (fig 8D) highlighted "cancer," "deep learning," "ultrasonic imaging," "postmenopausal women," and "sonography" as having the highest burst intensity. Keywords such as "machine learning," "ultrasonic imaging," "convolutional neural network," "case report," "pathological complete response," "deep learning," "artificial intelligence," and "classification" have been notably prominent in recent years, suggesting emerging research hotspots. A keyword clustering network diagram and temporal analysis (fig 8E) identified eight clusters, including "axial lymph node," "photographic thermography," "break region," "dense break," "break-preserving surgery," "postmenopausal women," "case report," and "molecular subtype." Notably, "break region," "dense break," and "break-preserving surgery" have been significant topics in the research field from 2004 to 2024.

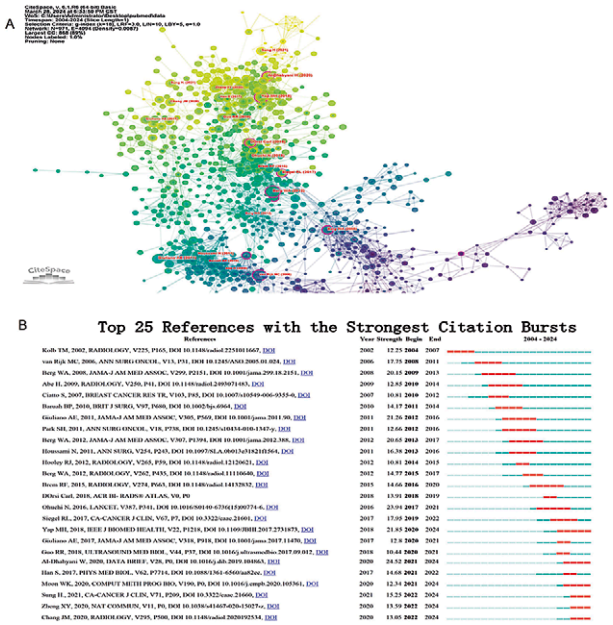


Fig 7. Analysis of key literature. (A) Co-citation network analysis of literature; (B) Top 25 references with the strongest citation bursts.

Discussion

Bibliometrics is a sub-discipline that employs mathematical and statistical methods to examine the distribution and development patterns of academic literature. By collecting, organizing, analyzing, and interpreting extensive literature data, bibliometrics enables researchers to swiftly grasp the current status, hotspots, and emerging trends within a specific field, thereby offering theoretical support and practical guidance for clinical practice and medical research [9]. In this study, we utilized two widely recognized bibliometric analysis tools, VOSviewer and CiteSpace, to analyze global literature on the US diagnosis of breast cancer over the past two decades. A total of 3,523 articles were included in the analysis. Throughout the period from 2004 to 2024, the number of published papers exhibited fluctuations but showed an overall upward trend, indicating an increasing research interest in US diagnosis of breast cancer. Additionally, the academic field's H-index for the 3,523 articles was 111, demonstrating that the included research has considerable academic impact and that the findings in the US diagnosis of breast cancer are widely cited and acknowledged.

Based on publication volume statistics, China leads with the highest number of publications among 82 countries/regions. However, the United States surpasses all other countries in terms of total citations, local citations, and average citations, while the United Kingdom has the highest average number of local citations. This indicates

that American scholars hold a prominent position in this research field. Despite China's leading publication volume, the quality of its research lags behind that of the United States, the United Kingdom, and other countries. Consequently, Chinese scholars need to enhance both the quality and impact of their research. The cooperation network analysis reveals that the United States engages in the most frequent international collaborations, with the highest frequency of cooperation occurring between the United States and China. South Korea's top three institutions lead in the number of publications, underscoring the country's active role and strong research capabilities in the field of US diagnosis of breast cancer. In terms of citations, the leading institutions are from the United States, Canada, and France, highlighting the extensive attention and recognition received by research in Europe and the United States, and its high importance in the field. Annual publication trends show that Sun Yat-sen University in China began focusing on US diagnosis of breast cancer in 2012, indicating a relatively late start in this research area. This late initiation may contribute to the lower academic impact of Chinese research findings, further emphasizing the need for Chinese scholars to improve research quality and influence. According to the Total Link Strength (TLS), institutions such as Shanghai Jiaotong University and Sun Yat-sen University in China, along with Yonsei University and Seoul National University in Korea, not only have high publication outputs but also exhibit significant intermediary centrality. This suggests that both China and Korea possess considerable influence in the field of US diagnosis of breast cancer and maintain substantial collaborative relationships with other institutions.

The top three high-yielding authors in the field of US diagnosis of breast cancer are Ki EK [10],Moon WK [11] and Kim MJ [12]. Among these, Cho N [13], stands out for having the highest average citation count and local citation count, as well as the highest TLS. Additionally, Korean expert Chang JM [14] is recognized as the most influential author in the mid-term of this research field. This indicates that Korea has established a leading research authority in the domain of US diagnosis of breast cancer. Further analysis of high-yield authors reveals that Chang C [15] from South Korea, along with Zhang L [16] and Wang Y [17] from China, are emerging figures in recent research on US diagnosis of breast cancer. This trend underscores the growing research capabilities and expertise of China in this field, reflecting an overall enhancement in China's scientific research level and influence.

The journal with the highest number of publications in the field of US diagnosis of breast cancer is Ultrasound Med Biol, followed by Breast Cancer and Eur Radiol.

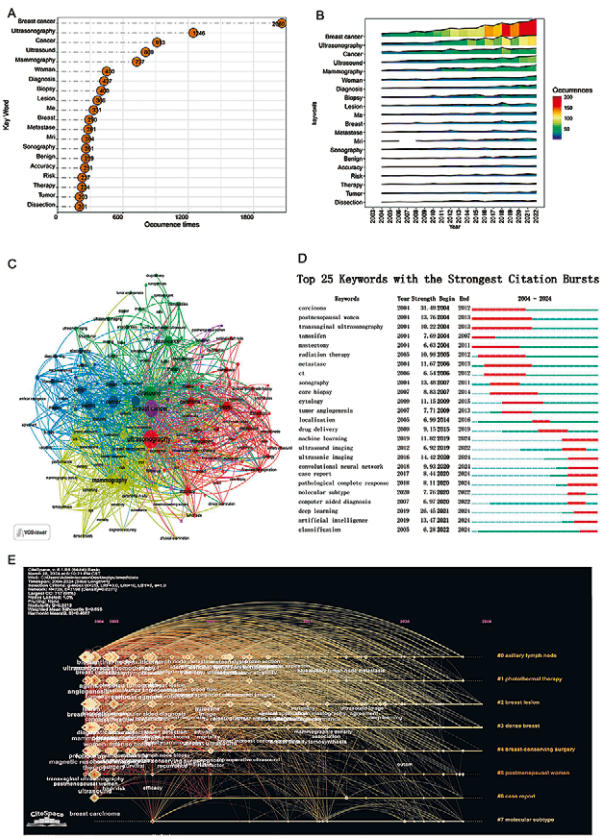


Fig 8. Keyword analysis. (A) frequency statistics of the top 20 keywords; (B) annual frequency analysis of the top 20 keywords; (C) co-occurrence network analysis of keywords; (D) burst analysis of keywords. The green line represents the timeline, with the red segments on the green timeline indicating periods of citation bursts, including the start year, end year, and duration of the burst; (E) temporal view of keywords. The position of nodes on the horizontal axis represents the year when the keyword first appeared, and the size of the nodes is positively correlated with the frequency of keyword occurrences. Lines between nodes indicate co-occurrence relationships.

Radiology journals, in particular, receive significantly more citations than other journals, underscoring their substantial academic influence in this area. Co-citation analysis reveals that Ultrasound Med Biol, Radiology, Ann Surg Oncol, and Eur Radiol have the highest Total Link Strength (TLS) values, highlighting their prominence and academic impact in US breast cancer research. The clustering results of cited journals indicate a focus on molecular/biological/genetic studies and health/nursing/medicine. Research in the molecular/biological/genetic domain often delves into the molecular mechanisms, gene variations, protein expressions, genetic characteristics, and molecular markers associated with breast cancer, as well as their relationship with US diagnostic outcomes [18,19]. Meanwhile, the health/nursing/medicine cluster primarily addresses the practical application

of diagnostic technologies, the evaluation of diagnostic accuracy, and their implications for breast cancer treatment and patient prognosis [20,21]. This broad attention to molecular, biological, and genetic aspects, combined with clinical practice and nursing, highlights the interdisciplinary nature of current research. Such a comprehensive approach is likely to drive ongoing advancements and refinements in US technology for breast cancer diagnosis.

Analyzing the most cited literature in the field of US diagnosis of breast cancer offers valuable insights into prevailing research directions and focal points. The highest Global Citation Score (GCS) in this field was achieved by Siu AL with the 2016 article titled "Screening for Breast Cancer: U.S. Preventive Services Task Force Recommendation Statement [22]," published in the Ann Intern Med. This seminal work has been cited 1,256 times, reflecting its substantial impact. Another highly influential piece is the 2020 article by Al Dhabyani W, "Dataset of Breakthrough Ultrasound Images," published in Data Brief. This study provides a comprehensive dataset of breast US images, which is instrumental for the automatic identification and classification of breast lesions [23]. The article's high citation intensity of 24.52 underscores its significance in advancing breast cancer detection algorithms. Additionally, the article "Detection of Breast Cancer with Addition of Annual Screening Ultrasound or a Single Screening MRI to Mammography in Women with Elevated Breast Cancer Risk" is also noteworthy [24]. This research emphasizes the value of annual US screenings for high-risk women. It highlights how advancements in US technology enable precise detection of even very small tumors, providing detailed information on tumor location, size, shape, blood flow distribution, and potential lymph node or distant metastasis. This study underscores the importance of US in staging, treatment planning, and prognosis evaluation for breast cancer. The prevalent focus in the cited literature is on the role of US screening in breast cancer diagnosis, reflecting its critical role in enhancing detection and management practices.

Analyzing the frequency of keywords in literature provides valuable insights into the research hotspots, trends, and primary concerns within a specific field. It also aids in evaluating the depth and breadth of research on a particular topic. In this study, the top five most frequently occurring keywords were "breast cancer," "ultrasound scanning," "tumor," "ultrasound", and "mammography." Most of these keywords exhibited a fluctuating upward trend between 2004 and 2024. This trend indicates that the primary focus during this period has remained on the clinical application of US for breast cancer diagnosis. The fluctuating upward trend likely reflects ongoing advancements and growing interest in US diagnostic technology. Keyword co-occurrence analysis helps identify key research areas and emerging frontiers in US diagnosis of breast cancer. In this study, five distinct clusters were identified, each focusing on different aspects of breast cancer diagnosis, including clinical efficacy, prognosis, and US imaging characteristics. Emergence analysis, which detects sudden increases or decreases in keyword frequency over time, can reveal emerging trends and research hotspots. Recent highlight analysis identified "machine learning," "ultrasonic imaging," "convolutional neural network," "case report," "pathological complete response," "deep learning," "artificial intelligence," and "classification" as the most frequently used keywords in the past five years. This suggests a shift towards rapid advancements and innovations in artificial intelligence within the field of breast US diagnosis. Such trends point to potential breakthroughs and new directions for future research. The construction of keyword clustering network graphs and time series analysis revealed that terms such as "breast density," "dense breast," and "breast-conserving surgery" have been consistent research focuses from 2004 to 2024. This highlights the sustained attention and in-depth research on breast cancer diagnosis and classification, the correlation between breast density and cancer risk, and advancements in breast-conserving surgical techniques.

This study represents the first bibliometric analysis and visualization of publications on the US diagnosis of breast cancer. The findings indicate a continued growth in the annual number of papers published in this field. China and the United States lead in terms of publication volume, citations, and international collaboration. However, the quality of Chinese papers is relatively lower compared to those from the United States, suggesting a need for improvement in research quality. Current research focuses and emerging trends include the integration of machine learning and artificial intelligence in the pathological diagnosis and treatment of breast cancer. Key topics such as "ultrasonic imaging," "convolutional neural networks," "complete pathological response," "deep learning," and "artificial intelligence" are prominent in the field, reflecting its advanced and innovative direction. This study does have some limitations. The number of citations can be influenced by the publication date, potentially leading to a lack in recognizing high-quality literature published in the past two years. Additionally, the analysis is based solely on literature from the Web of Science Core Collection, which may result in the exclusion of relevant studies from other databases.

Conflict of interest: none

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