Research Trends of Artificial Intelligence in Gastric Cancer Diagnosis and Treatment: A 20-Year Bibliometric Analysis (Postprint)

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Date: 2023-07-31T00:00:00+00:00

Abstract

Background In recent years, research on applying artificial intelligence (AI) to the diagnosis and treatment of gastric cancer has been increasing, but no researchers have yet conducted a systematic analysis using bibliometric analysis methods. Objective To analyze relevant research on the application of AI in gastric cancer diagnosis and treatment, and to explore research hotspots and development trends from 2003 to 2022.

Methods On November 6, 2022, a computer-based search was conducted on the Web of Science (WOS) Core Collection database to retrieve relevant studies on the application of AI in gastric cancer diagnosis and treatment. Through bibliometric analysis methods, VOSviewer 1.6.18 software was used for visual analysis of collaboration among countries (regions), institutions, and authors, co-cited authors, and keyword co-occurrence and overlay. CiteSpace 5.7.R5 software was used for institutional betweenness centrality analysis, journal dual-map overlay analysis, co-cited literature cluster analysis for the past six years, co-cited literature cluster timeline analysis, and reference burst analysis. Excel 2019 software was used to generate bar charts of publication volume and descriptive analysis tables for countries (regions), institutions, journals, authors, co-cited authors, cited references, and keywords.

Results A total of 703 articles were included. The annual publication volume of research on AI application in gastric cancer diagnosis and treatment from 2003 to 2022 showed an overall upward trend, with rapid growth after 2017, and the most rapid increase occurring from 2019 to 2021. The country (region), institution, and author with the highest publication output were China, the Chinese Academy of Sciences, and TADA TOMOHIRO, respectively. The top three co-cited authors, BRAY FREDDIE, HIRASAWA TOSHIAKI, and JIANG YUMING, have made significant contributions to this field. Frontiers

in Oncology was the journal with the highest number of publications, while Gastrointestinal Endoscopy was the most influential journal among the top 10 journals publishing research on AI application in gastric cancer diagnosis and treatment. The fields of citing journals were mainly concentrated in two areas: "Medicine, Medical, Clinical" and "Molecular, Biology, Immunology"; the fields of cited journals were mainly concentrated in "Molecular, Biology, Genetics" and "Health, Nursing, Medicine". The most frequently co-cited reference was "Global cancer statistics 2018: GLOBOCAN estimates of incidence and mortality worldwide for 36 cancers in 185 countries". According to keyword clustering results, all keywords could be divided into four categories: AI-assisted biological research of gastric cancer, AI-assisted endoscopic diagnosis of gastric cancer, AI-assisted pathological diagnosis of gastric cancer, and AI-assisted non-endoscopic treatment and prognosis prediction of gastric cancer. Deep learning, convolutional neural networks, radiomics, gastrointestinal endoscopy, pathology, and immunotherapy are current research hotspots.

Conclusion AI has broad application prospects in gastric cancer diagnosis and treatment, and an increasing number of scholars are dedicated to conducting AI research on gastric cancer diagnosis and treatment. Currently, AI has been extensively studied in gastric cancer biology, diagnosis, staging, efficacy evaluation, and prognosis prediction. The findings of this study can provide references for scholars engaged in AI and gastric cancer-related research.

Full Text

Research Trends in Artificial Intelligence in Gastric Cancer Diagnosis and Treatment: A 20-Year Bibliometric Analysis

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Abstract

Background In recent years, research on applying artificial intelligence (AI) to gastric cancer diagnosis and treatment has been increasing, yet no systematic bibliometric analysis of this field has been conducted. **Objective** To analyze research on AI applications in gastric cancer diagnosis and treatment and explore research hotspots and development trends from 2003 to 2022. **Methods** On November 6, 2022, we systematically searched the Web of Science (WOS) Core Collection database for studies on AI applications in gastric cancer diagnosis and treatment. Using bibliometric analysis, we employed VOSviewer 1.6.18 to visualize collaborations among countries/regions, institutions, and authors,

as well as co-cited authors and keyword co-occurrence and overlay patterns. CiteSpace 5.7.R5 was used for institutional betweenness centrality analysis, journal dual-graph overlay analysis, clustering analysis of co-cited literature from the past six years, co-cited literature clustering timeline analysis, and reference burst detection. Excel 2019 was used to generate publication volume bar charts and descriptive analysis tables for countries/regions, institutions, journals, authors, co-cited authors, cited references, and keywords. **Results** A total of 703 articles were included. Annual publication volume showed an overall upward trend from 2003 to 2022, with rapid growth after 2017 and the most rapid increase occurring from 2019 to 2021. China, the Chinese Academy of Sciences, and TADA TOMOHIRO were the top publishing country, institution, and author, respectively. The three most frequently co-cited authors—BRAY FREDDIE, HIRASAWA TOSHIAKI, and JIANG YUMING—have made significant contributions to the field. Frontiers in Oncology published the most articles, while Gastrointestinal Endoscopy was the most influential journal among the top 10 journals publishing AI-related gastric cancer research. Citing journals primarily focused on "Medicine, Medical, Clinical" and "Molecular, Biology, Immunology," while cited journals concentrated on "Molecular, Biology, Genetics" and "Health, Nursing, Medicine." The most frequently co-cited reference was "Global cancer statistics 2018: GLOBOCAN estimates of incidence and mortality worldwide for 36 cancers in 185 countries." Keyword clustering revealed four categories: AI-assisted biological research of gastric cancer, AI-assisted endoscopic diagnosis, AI-assisted pathological diagnosis, and AI-assisted non-endoscopic treatment and prognosis prediction. Current research hotspots include deep learning, convolutional neural networks, radiomics, gastrointestinal endoscopy, pathology, and immunotherapy. **Conclusion** AI has broad application prospects in gastric cancer diagnosis and treatment, with increasing numbers of scholars devoted to this field. AI has been widely studied in gastric cancer biology, diagnosis, staging, efficacy assessment, and prognosis prediction. These results can provide a reference for researchers engaged in AI and gastric cancer-related research.

Keywords: Gastric cancer; Artificial intelligence; Diagnosis; Treatment; Visual analysis; Bibliometrics; VOSviewer; CiteSpace

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1.1 Data Sources

On November 6, 2022, we searched the Web of Science (WOS) Core Collection database to retrieve studies on AI applications in gastric cancer diagnosis and treatment. The search strategy was: ((((TS=(Stomach Neoplasm*)) OR TS=(Gastric Neoplasm*)) OR TS=(Cancer of Stomach)) OR TS=(Stomach Cancer)) OR TS=(Gastric Cancer)) AND ((((((((((((((((((((TS=(artificial intelligence)) OR TS=("computational intelligence")) OR TS=("deep learning")) OR TS=("computer aided")) OR TS=("machine learning")) OR TS=("support vector machine")) OR TS=("data learning")) OR TS=("artificial neural net-

work")) OR TS=("digital image")) OR TS=("convolutional neural network")) OR TS=("evolutionary algorithms")) OR TS=("feature learning")) OR TS=("reinforcement learning")) OR TS=("big data")) OR TS=("image segmentation")) OR TS=("image segmentation")) OR TS=("hybrid intelligent system")) OR TS=("recurrent processing")) OR TS=("bayesian network")) OR TS=("bayesian learning")) OR TS=("random forest")) OR TS=("evolutionary algorithms")) OR TS=("multiagent system"). We limited the language to "English" and document types to "article" and "review," with the publication period set from 2003 to 2022. Exclusion criteria were: (1) conference papers and commentaries; (2) literature with topics unrelated to this study; (3) duplicate publications. A total of 703 articles were included, and complete records with references were exported and saved in "download_{txt}" format.

1.2 Statistical Methods

We used VOSviewer 1.6.18 and CiteSpace 5.7.R5 for bibliometric and visual analysis. Before analysis, we used CiteSpace 5.7.R5 to deduplicate the data exported from WOS, which remained 703 articles after deduplication. VOSviewer 1.6.18 was employed to visualize collaborations among countries/regions, institutions, and authors, as well as co-cited authors and keyword co-occurrence and overlay patterns. CiteSpace 5.7.R5 was used for institutional betweenness centrality analysis, journal dual-graph overlay analysis, clustering analysis of co-cited literature from the past six years, co-cited literature clustering timeline analysis, and reference burst detection. Keyword co-occurrence analysis aims to identify structural distributions of research hotspots through thematic co-occurrence, while keyword overlay analysis reveals evolutionary trends by incorporating temporal factors into keyword co-occurrence networks. Journal dual-graph overlay analysis displays disciplinary distribution and citation trajectories by clustering and overlaying citing and cited journals. Co-cited literature clustering analysis identifies influential literature and reflects research development dynamics by analyzing how frequently documents are cited together. Co-cited literature clustering timeline analysis shows the temporal span of research foundations by examining relationships between clusters and citation patterns within clusters. Reference burst detection identifies emerging references with high frequency change rates and rapid growth to analyze research frontiers. Additionally, Excel 2019 was used to plot publication volume bar charts and descriptive analysis tables for countries/regions, institutions, journals, authors, co-cited authors, cited references, and keywords.

2.1 Publication Volume and Trend Analysis

Among the 703 included articles, 596 (84.8%) were original research and 107 (15.2%) were reviews. Before 2016, annual publication volume was low and grew slowly, with the maximum annual output reaching 195 articles in 2022 (as of November 6, 2022), approximately 20 times that of 2016 [Figure 1: see original

paper]. Publications from the past six years accounted for 90.3% (635/703) of the total. Polynomial fitting results showed R^2=0.9336, indicating a significant correlation between publication year and annual volume, suggesting that publications in this field will continue to increase. This indicates that AI applications in gastric cancer diagnosis and treatment remain a research priority.

2.2 Country/Region Analysis

Publications in this field originated from 52 countries/regions, with only China publishing more than 100 articles and 25 countries/regions publishing $ $5 articles. Table 1 summarizes the top 10 countries/regions by publication volume over the past 20 years. China ranked first (366 articles), followed by the United States (93), South Korea (86), Japan (79), and Germany (47). The top five countries/regions by total citations were China (4,371), United States (2,704), Japan (2,232), Germany (1,189), and South Korea (890). Although Chinese publications had the highest total citations, the average citation counts for publications from the Netherlands, United States, United Kingdom, Japan, Germany, and Italy were all higher than those from China. Based on VOSviewer analysis of international collaboration [Figure 2: see original paper], where lines between nodes indicate collaborative relationships and thicker lines represent stronger ties (higher total link strength, TLS), the top five countries by TLS were China, Japan, United States, Germany, and South Korea.

2.3 Institution Analysis

A total of 1,162 institutions contributed to AI applications in gastric cancer diagnosis and treatment, with 74 institutions publishing $ $5 articles. Table 2 summarizes the top 10 institutions by publication volume over the past 20 years. The top three institutions were the Chinese Academy of Sciences (32 articles), Sun Yat-sen University (25), and Shanghai Jiao Tong University (25). Based on VOSviewer analysis of institutional collaboration networks for institutions with $ $5 publications [Figure 3: see original paper], the top three institutions by TLS were the Tomohiro Tada Institute of Gastroenterology and Proctology (416), Chinese Academy of Sciences (392), and University of Tokyo (360). Betweenness centrality measures node importance in networks, and in CiteSpace-generated maps, nodes with purple outer circles indicate high betweenness centrality. CiteSpace analysis revealed that the Chinese Academy of Sciences (0.19), Sungkyunkwan University (0.17), Wuhan University (0.16), Harvard University (0.12), Sun Yat-sen University (0.11), and China Medical University (0.11) were high-betweenness-centrality institutions playing important roles in this field.

2.4 Journal Publication and Co-citation Analysis

The 703 articles were published in 330 journals, with 26 journals publishing $ $5 articles. The top 10 journals published 156 articles (22.2% of total). Frontiers

in Oncology published the most articles (32), Gastric Cancer had the most citations (519), and Gastrointestinal Endoscopy had the highest 2022 impact factor (10.396). Five journals were in Q2 category, as shown in Table 3 . The most frequently co-cited journal was Gastrointestinal Endoscopy (1,004 co-citations), followed by Gastric Cancer (702) and Endoscopy (631), as shown in Table 4 . Journal dual-graph overlay analysis revealed four main citation paths. Citing journals primarily focused on "Medicine, Medical, Clinical" and "Molecular, Biology, Immunology," while cited journals concentrated on "Molecular, Biology, Genetics" and "Health, Nursing, Medicine" [Figure 4: see original paper].

2.5 Author and Co-cited Author Analysis

This field involved 4,088 authors and 16,338 co-cited authors. Table 5 shows the top 10 authors by publication volume and co-citation frequency. TADA TOMOHIRO published the most articles (16), followed by TIAN JIA (11) and YU HONGGANG (10). The most frequently co-cited author was BRAY FREDDIE (186 co-citations), followed by HIRASAWA TOSHIAKI (122) and JIANG YUMING (111). Author collaboration networks are shown in [Figure 5: see original paper], and author co-citation mapping is presented in [Figure 6: see original paper].

2.6 Reference Citation Analysis

A total of 22,273 references were cited, with 76 references receiving $ $20 co-citations. Table 6 provides details on the top 10 most co-cited references. The most frequently co-cited reference was "Global cancer statistics 2018: GLOBOCAN estimates of incidence and mortality worldwide for 36 cancers in 185 countries" by BRAY FREDDIE et al. (183 co-citations), followed by "Application of artificial intelligence using a convolutional neural network for detecting gastric cancer in endoscopic images" by HIRASAWA TOSHIAKI et al. (113 co-citations) and "Application of convolutional neural network in the diagnosis of the invasion depth of gastric cancer based on conventional endoscopy" by ZHU YAN et al. (78 co-citations). Given that most of the 703 included articles were published between 2017-2022, clustering analysis of co-cited literature from the past six years can better identify research frontiers. As shown in [Figure 7: see original paper], co-cited literature from the past six years formed 10 clusters, with endoscopy, digital pathology, radiomics, image classification, and system biology related to gastric cancer diagnosis and staging. The co-cited literature clustering timeline [Figure 8: see original paper] shows that endoscopy, digital pathology, radiomics, and image classification are current research hotspots, while system biology was the earliest research hotspot. [Figure 9: see original paper] displays the top 15 references with the strongest citation bursts. Citation bursts in this field began in 2016, with numerous references still being frequently cited, indicating that AI applications in gastric cancer diagnosis and treatment will remain a research hotspot in coming years.

2.7 Keyword Co-occurrence and Overlay Analysis

A total of 2,609 keywords appeared 4,977 times, with 95 keywords appearing $ $10 times. Table 7 shows the top 10 keywords by frequency. Keywords appearing >100 times included gastric cancer, deep learning, artificial intelligence, classification, cancer, and diagnosis. VOSviewer-generated keyword co-occurrence network mapping [Figure 10: see original paper] identified four clusters: red cluster (AI-assisted biological research of gastric cancer) included keywords such as gene, expression, gene-expression, and biomarkers; blue cluster (AI-assisted endoscopic diagnosis) included gastrointestinal endoscopy, capsule endoscopy, and upper-gastrointestinal endoscopy; yellow cluster (AI-assisted pathological diagnosis) included pathology, digital pathology, and histology; green cluster (AI-assisted non-endoscopic treatment and prognosis prediction) included chemotherapy, immunotherapy, surgery, and outcome. The keyword overlay network [Figure 11: see original paper] shows temporal trends, with yellow nodes representing emerging keywords that may indicate current research hotspots. Deep learning, convolutional neural network, radiomics, gastrointestinal endoscopy, pathology, and immunotherapy are keywords that have frequently appeared in the past two years and may become future research hotspots.

Discussion

This study used two commonly used bibliometric analysis software tools, VOSviewer and CiteSpace, to conduct visual analysis of research on AI applications in gastric cancer diagnosis and treatment over the past 20 years, objectively describing the current status, development trends, and future research hotspots in this field. Publication volume statistics indicate that publications from the past six years account for 90.3% of the total, with annual output expected to continue increasing, demonstrating that AI has gained substantial development in gastric cancer diagnosis and treatment in recent years. China far exceeds other countries/regions in publication volume, but the average citation count for Chinese publications is significantly lower than that for publications from the Netherlands, United States, United Kingdom, Japan, and Germany. This may be related to China's relatively late start in AI applications for gastric cancer diagnosis and treatment, resulting in lower academic impact of research findings. Therefore, Chinese scholars should focus on improving research quality and influence. The United States ranks second in both publication volume and average citation count, indicating that American scholars occupy an important position in this research field. Based on TLS, China, the United States, and Japan have more collaborations with other countries/regions. Among the top 10 institutions by publication volume, seven are from China. The Chinese Academy of Sciences not only has the highest publication volume and strong TLS but also the highest betweenness centrality, indicating its high influence in this field and extensive collaborations

with other institutions.

The top five journals by publication volume are Frontiers in Oncology (2022 IF: 5.738, JCR Q2), Scientific Reports (2022 IF: 4.996, JCR Q2), Cancers (2022 IF: 6.675, JCR Q1), Gastrointestinal Endoscopy (2022 IF: 10.396, JCR Q1), and World Journal of Gastroenterology (2022 IF: 5.374, JCR Q2). Gastrointestinal Endoscopy has the highest impact factor and most co-citations, indicating its high academic influence in this field. Future research in this area will likely be published in these journals. Citing journals primarily focus on two fields, while cited journals also concentrate on two fields, suggesting that interdisciplinary collaboration is needed when applying AI to gastric cancer diagnosis and treatment.

The top 10 most co-cited references reflect hotspot directions in AI applications for gastric cancer diagnosis and treatment, with most content concerning endoscopic diagnosis of gastric or early gastric cancer. The most co-cited reference by BRAY et al. [9] provides global cancer statistics across 185 countries. The second most co-cited reference by HIRASAWA et al. [10] in Gastric Cancer introduced a convolutional neural network system for automatic gastric cancer detection from endoscopic images with high sensitivity, serving as an auxiliary tool for endoscopists. The co-cited literature clustering timeline shows that biological characteristics of gastric cancer [7,11] were early research hotspots, which later shifted to digital pathological diagnosis [12,13] and radiomics analysis [14-17].

Keyword clustering analysis identified four categories: AI-assisted biological research, endoscopic diagnosis, pathological diagnosis, and non-endoscopic treatment/prognosis prediction. Based on publication volume statistics, we analyzed keyword clustering results across two periods. In the first period (2003-2016), research primarily focused on gastric cancer classification and diagnosis, including biomarker detection [18], endoscopic diagnosis [19], and lymph node metastasis prediction, though with limited analytical techniques and small datasets. In contrast, AI research in other cancers like prostate cancer focused on screening and surgical treatment [20]. In the second period (2017-2022), annual publication volume grew rapidly, with computer-aided diagnosis becoming the main application direction. Deep learning emerged as the most frequent AI method due to its stable and excellent performance and has been applied to endoscopic diagnosis [21], pathological diagnosis [22], staging [23-24], and efficacy/prognosis prediction [16,25], consistent with research hotspots shown in the keyword overlay map.

Compared with endoscopists, deep learning-based computer-aided diagnosis systems are not limited by clinical experience, helping improve diagnostic accuracy across different experience levels, reducing misdiagnosis and missed diagnosis, and achieving higher diagnostic performance [26]. Lesions occurring in non-neoplastic epithelium and subepithelium are difficult to identify with image-enhanced endoscopy [27], but the combination of Raman spectroscopy with endoscopy and AI may compensate for current endoscopic limitations. Addi-

tionally, deep learning models supporting pathological image segmentation can help eliminate adverse effects of subjective bias during pathological specimen examination and alleviate the shortage of well-annotated pathological image data [28]. Co-inhibitory signaling pathways mediated by immune checkpoints such as PD-1/PD-L1 and CTLA-4 play important roles in tumor-induced immunosuppression [29]. Microsatellite instability and Epstein-Barr virus (EBV) positivity are biomarkers for better long-term prognosis in gastric cancer patients, and both subtypes (microsatellite instability type, EBV-positive type) show potential susceptibility to immune inhibitors. Deep learning models can detect microsatellite instability and EBV positivity from hematoxylin-eosin stained gastric cancer tissue sections, serving as a screening tool for populations requiring molecular testing and predicting patient response to immunotherapy [25]. Deep learning models based on computed tomography images can help radiologists assess gastric cancer lymph node metastasis [30], serosal invasion [31], and peritoneal metastasis [32], guiding preoperative treatment and avoiding unnecessary surgery and complications. The integration of endoscopy, imaging recognition, and biomarker screening technologies with AI provides more possibilities for gastric cancer detection, treatment, and monitoring.

Conclusion

This study demonstrates that AI has been widely applied in gastric cancer diagnosis and treatment, with annual publication volume expected to continue growing. The United States dominates this field, and Chinese scholars should strengthen exchanges and collaborations with international colleagues to enhance the academic impact of Chinese research. Deep learning, convolutional neural networks, radiomics, and other AI technologies for assisting endoscopic diagnosis, pathological diagnosis, and immunotherapy represent current research hotspots and frontier directions. Developing AI systems supporting real-time endoscopic diagnosis, pathological diagnosis, and integrated diagnosis combining genomics and proteomics may be future research priorities. Due to AI's efficient learning and computing capabilities, it will be further promoted in the future. However, AI will not completely replace physicians in clinical practice; combining human services with AI can compensate for shortages in medical resources and specialist endoscopists and pathologists in some countries/regions and medical institutions, achieving new breakthroughs in AI applications for gastric cancer diagnosis and treatment.

This study has limitations: citation counts are affected by publication time, so high-quality literature published in 2022 may not have reached ideal citation levels, potentially causing temporal delays in identifying research frontiers. Additionally, this analysis only included English literature from the WOS Core Collection database, potentially omitting relevant literature in other languages.

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Author Contributions: DONG Na drafted and revised the manuscript; CUI Ting determined research content and conducted data retrieval; WANG Lulu and SHI Ronghui generated visualizations using VOSviewer and CiteSpace; FENG Jie guided data analysis; HUANG Xiaojun was responsible for quality control and final approval.

Conflict of Interest: The authors declare no conflict of interest.

Funding: Gansu Provincial Youth Science and Technology Fund (21JR1RA155); Lanzhou University Second Hospital Cuiying Science and Technology Innovation Program (2020QN-12)

Data Availability: The datasets generated and analyzed during this study are available from the corresponding author upon reasonable request.

Ethical Approval: Not applicable.

Informed Consent: Not applicable.

Acknowledgments: Not applicable.

Received: December 29, 2022; Revised: July 4, 2023; Accepted: [Epub ahead of print]

Edited by: CHEN Junshan

Note: Figure translations are in progress. See original paper for figures.