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CiteSpace-Based Visual Analysis of Artificial Intelligence in Early Warning Nursing for Postoperative Complications of Gastrointestinal Tumors

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Abstract

Objective: To systematically sort out research hotspots, evolutionary stages and emerging frontiers of artificial intelligence (AI) applied in predictive early warning nursing for postoperative complications of gastrointestinal tumors via bibliometric visualization, so as to provide theoretical references for constructing intelligent perioperative nursing systems. **Methods:** Literature was retrieved from Web of Science Core Collection (WoSCC) on July 12, 2026 with a combined subject-term retrieval formula. Initial 136 records were deduplicated and screened by two researchers. Eligible English original articles and reviews published before July 12, 2026 were retained; conference abstracts, editorials and studies irrelevant to nursing early warning were excluded, leaving 120 papers for analysis via CiteSpace 6.3.R1. Analyses included keyword co-occurrence, clustering, citation burst detection and timeline mapping. **Results:** Publications grew exponentially after 2021, with 8 papers released by July 2026. China contributed the most papers (60, 50.0%), followed by the US (12). The keyword network contained 230 nodes and 338 links, forming 10 reliable clusters (Q = 0.6501, S = 0.8821). Main hotspots cover machine learning-based complication prediction models and electronic health record-based individualized risk stratification. "Risk prediction" and "prevention" are the 2025-2026 frontiers, shifting research focus from passive treatment to proactive predictive nursing. **Conclusion:** The research field of AI-driven early warning nursing for gastrointestinal tumor postoperative complications has entered a rapid development phase. Chinese scholars dominate total publication volume, while international cross-regional collaborative nursing research needs further rein-

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forcement. Future research should prioritize developing interpretable, real-time intelligent warning tools compatible with clinical nursing workflows, and carry out multi-center prospective nursing verification to accelerate the clinical translation of AI technology, ultimately optimizing perioperative nursing quality and postoperative recovery outcomes of gastrointestinal tumor patients.

Keywords

Gastrointestinal Neoplasms, Postoperative Complications, Artificial Intelligence, Machine Learning, Early Warning Nursing, Bibliometrics, CiteSpace

1. Introduction

Gastrointestinal tumors (gastric and colorectal cancer) create a substantial global cancer burden, with surgical resection as the primary curative treatment [1]. Postoperative complications including anastomotic leakage, surgical site infection, venous thromboembolism and organ dysfunction occur in 15% - 40% of patients, delaying recovery, raising medical costs and increasing mortality [2]-[4].

Conventional postoperative nursing assessment depends on nurses' manual monitoring of vital signs, lab results and subjective symptoms, which suffers from subjective evaluation, delayed detection of hidden complications and insufficient individualized risk stratification. Artificial intelligence and machine learning enable clinical pattern identification and automated risk modeling; AI early warning systems integrated into nursing workflows analyze multimodal clinical data to generate real-time risk scores and deliver proactive nursing interventions [5]-[8].

Relevant studies on AI and gastrointestinal tumor postoperative complications have grown rapidly, yet no bibliometric analysis has focused on AI nursing early warning. Bibliometrics quantitatively identifies research hotspots, development trajectories, international cooperation and emerging frontiers via publication metadata [9] [10].

This study used CiteSpace to analyze global literature on AI-assisted early warning nursing for gastrointestinal tumor postoperative complications. Visual analyses covered annual output, national collaboration, keyword co-occurrence, clustering, citation bursts and timelines to illustrate field development and offer guidance for clinical nursing and further research. Since the earliest retrieved paper on this topic dated to 2008, the analysis timeframe was defined as 2008-July 12, 2026.

2. Materials and Methods

2.1. Data Source

All literature data were retrieved from the Web of Science Core Collection (WoSCC). The formal retrieval work was completed on July 12, 2026. WoSCC owns complete citation resources and standardized metadata, which can satisfy the data demands of bibliometric visual analysis.

2.2. Search Strategy

Retrieval was finished in the advanced search page of WoSCC. The topic field covering titles, abstracts and keywords was used. Subject terms and free words were matched together to form the search expression:

TS = ((artificial intelligence OR machine learning) AND (gastrointestinal neoplasms OR gastric cancer OR colorectal cancer) AND (postoperative complications) AND (early warning system OR risk prediction model OR nursing care))

Unified retrieval limits were set as below:

Time range: From the inception of WoSCC database to July 12, 2026;

Language: Only English papers were collected;

Document type: Only original research articles and reviews were included.

The specific inclusion criteria for "early warning nursing" were defined as follows: 1) Nursing Functions: Studies must involve at least one of the following nursing-specific activities: risk assessment, vital sign monitoring, symptom surveillance, patient education on complication recognition, or nurse-led intervention protocols triggered by AI alerts; 2) Care Settings: Inpatient surgical wards, intensive care units (ICUs), or transitional care facilities providing postoperative gastrointestinal tumor care; 3) Postoperative Complications: Studies addressing anastomotic leakage, surgical site infection, venous thromboembolism, hemorrhage, ileus, or organ dysfunction occurring within 30 days after surgery. Studies focusing solely on physician-driven diagnostic tools without nursing workflow integration were excluded.

Of 136 initially retrieved records, 4 duplicates were removed via EndNote X9. Title/abstract screening excluded 6 records (irrelevant topic: [n = 2]; non-nursing focus: [n = 2]; non-gastrointestinal tumor population: [n = 2]). Full-text review of the remaining 126 records further excluded 6 (no AI methodology: [n = 1]; no early warning/prediction component: [n = 1]; conference abstracts/editorials: [n = 4]). Ultimately, 120 publications were included.

2.3. Analytical Tool and Parameters

CiteSpace 6.3.R1 was used for all analyses with the following reproducible parameters: Time slicing was set from January 2008 to July 2026 with a slice length of 1 year per slice. Node type was selected as "Keyword." Selection criteria were set to Top N = 50 per slice. Pruning methods included Pathfinder and Pruning sliced networks. Clustering was performed using the Log-Likelihood Ratio (LLR) algorithm with automatic cluster labeling extracted from keywords. Citation burst detection used Kleinberg's algorithm with a minimum burst duration of 2 years and $\gamma = 1.0$. Network visualization thresholds were adjusted to ensure clarity while retaining key structural information.

3. Results

3.1. Annual Publication Output

The publication distribution is shown in **Figure 1**. The earliest paper dated to

2008. From 2008 to 2016, only 1 - 2 papers were released annually. Output grew steadily after 2019, peaking at 25 papers in 2025; 8 papers were recorded by July 2026. The total volume rose exponentially, with the 2025 output nearly 9.5 times that of 2019.

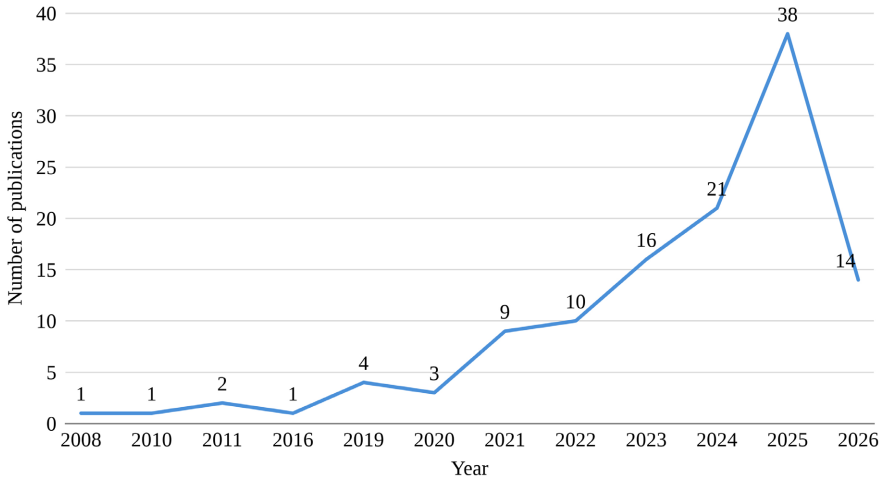

Figure 1. Annual publication output of AI in early warning nursing care for postoperative complications of gastrointestinal tumors.

3.2. Country Collaboration Analysis

The international cooperation network (**Figure 2**) contained 30 nodes and 27 links with density = 0.0621, indicating loose global collaboration. China ranked first with 60 papers (50%), followed by the US (12), Japan, South Korea, Iran, the Netherlands, India (7 each). The US had the highest centrality (0.85) as the core cooperation hub, while China's centrality was only 0.11 despite its large publication volume.

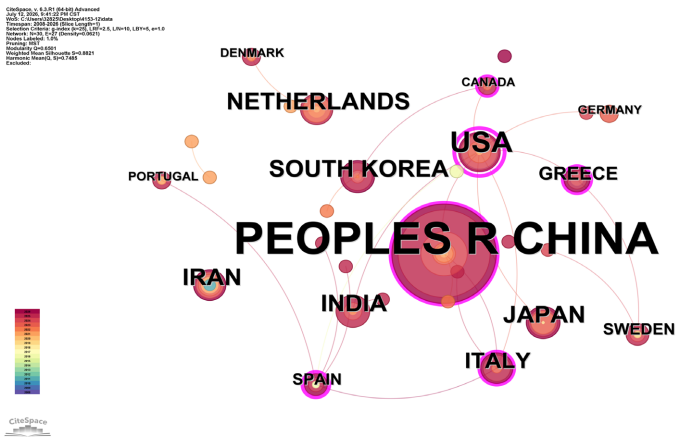

Figure 2. Country collaboration network visualization.

3.3. Keyword Co-Occurrence Analysis

The keyword network (**Figure 3**) included 230 nodes and 338 links (density =

0.0128), with 96% nodes in one connected component. The top frequent and high-centrality keywords were machine learning, gastric cancer, artificial intelligence and colorectal cancer. Core research focused on algorithm-based postoperative risk prediction and stratification for cancer patients.

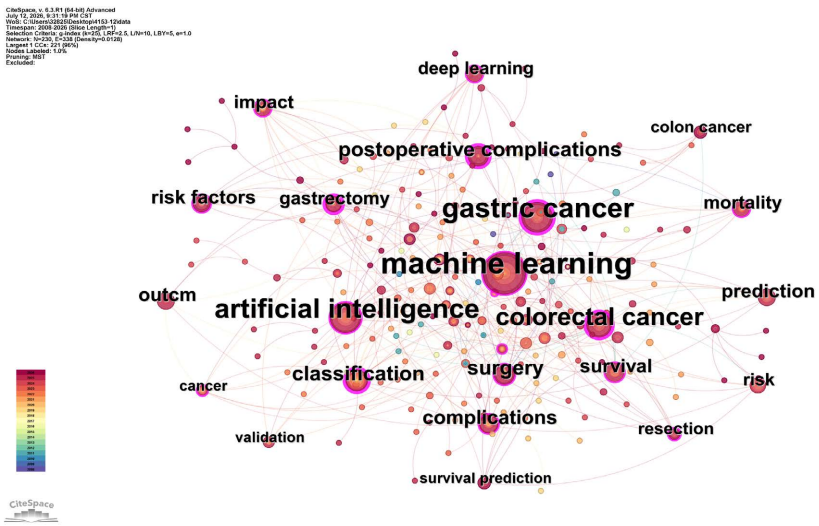

Figure 3. Keyword co-occurrence network visualization.

3.4. Keyword Clustering Analysis

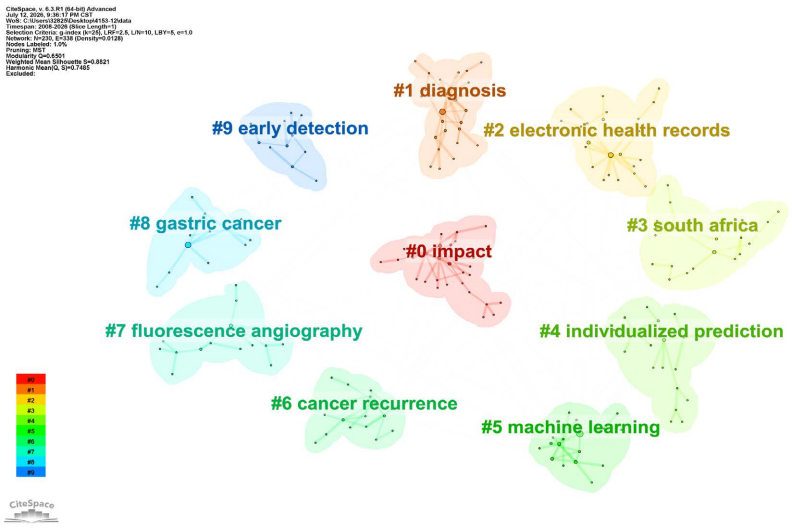

Figure 4. Keyword clustering visualization.

Ten stable keyword clusters (Figure 4) were extracted (Modularity Q = 0.6501, Mean Silhouette S = 0.8821, all silhouette > 0.8). Cluster #3 is labeled "South Africa" as a tentative observation based on its core co-occurring keywords including resource-limited settings, task-shifting, mobile health and nurse-led triage extracted from the cluster's retrieved records. This grouping preliminarily reflects a regional research orientation focused on low-cost, accessible AI early warning

tools adapted to resource-scarce medical environments, distinct from high-income regions that prioritize high-precision algorithm optimization. Relevant records within this cluster tentatively explore simplified mobile alert tools and task-shifting models for primary nurses, which may offer supplementary perspectives for expanding the universal applicability of AI nursing warning systems globally. Other mainstream clusters covered postoperative care improvement, endoscopic diagnosis, electronic health record mining, individualized risk scoring and intraoperative fluorescence angiography-assisted assessment. Cluster #4 (Individualized Prediction) represents personalized complication risk models using random forest and survival analysis. Cluster #5 (Machine Learning) centers on traditional ML algorithms for complication classification, including decision trees and logistic regression. Cluster #7 (Fluorescence Angiography) represents an emerging frontier utilizing AI-enhanced imaging technology for intraoperative assessment of anastomotic perfusion, directly relevant to preventing anastomotic leakage [11] [12].

3.5. Keyword Citation Burst Analysis

Twenty-five burst keywords were divided into three development phases (**Figure 5**):

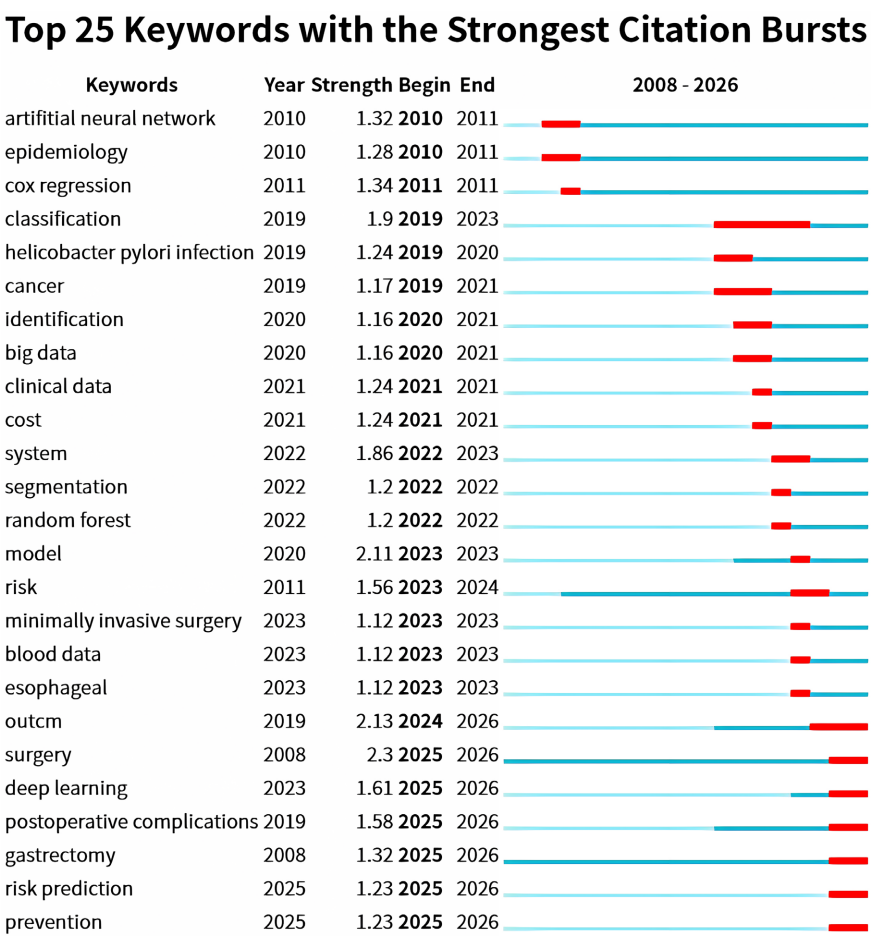

Figure 5. Top 25 keywords with the strongest citation bursts (2008-2026).

2010-2011: Classical statistical and neural network methods for surgical prognosis;

2019-2023: Clinical big data mining and standardized AI prediction models;

2024-2026: Deep learning, risk prediction and prevention became cutting-edge directions, shifting research focus from passive treatment to proactive predictive nursing.

3.6. Timeline Visualization Analysis

Timeline mapping (Figure 6) showed that Cluster #8 Gastric Cancer and Cluster #5 Machine Learning were the foundational research directions lasting from 2008 to 2026. The field evolved in three stages: simple surgical outcome observation (2008-2016), preliminary algorithm application (2016-2020), and comprehensive AI perioperative early warning system research (2020-2026). Fluorescence angiography (Cluster #7) was the latest emerging research hotspot.

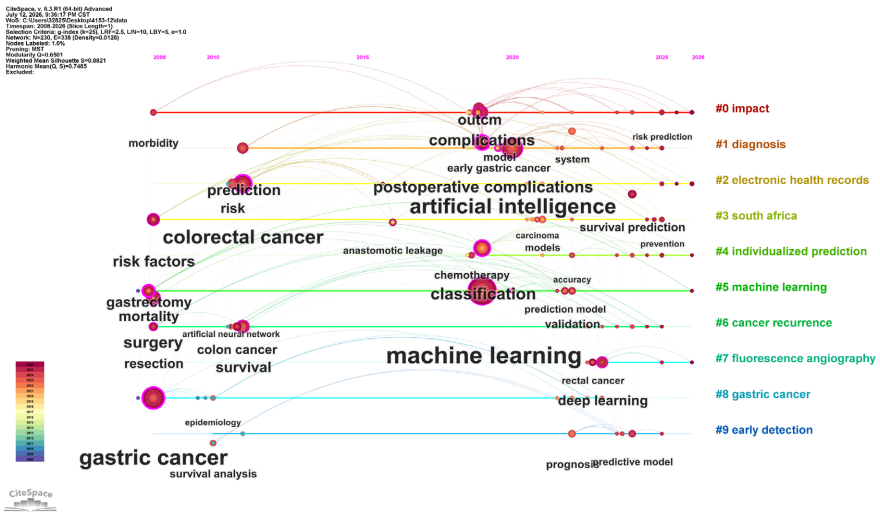

Figure 6. Timeline visualization of keyword clusters.

4. Discussion

4.1. Research Growth and Development Stages

The evolution of this field reflects a shift from theoretical exploration to clinical nursing integration. Early research (2008-2018) rarely addressed nursing-specific early warning needs, while the acceleration stage (2019-2022) saw AI models tailored for bedside risk assessment emerge alongside electronic nursing records. The current proliferation stage (2023-2026) is driven by urgent clinical demand for intelligent tools that enhance proactive postoperative nursing surveillance. Although China leads in publication volume due to abundant clinical resources and policy support, its limited international collaboration highlights a need for cross-cultural validation of nursing protocols. Future efforts should prioritize multinational partnerships to ensure AI-driven nursing interventions are generalizable across diverse healthcare settings, rather than focusing solely on domestic model

development [13]-[15].

4.2. Current Research Hotspots and Nursing Practice Implications

Three dominant hotspots directly inform nursing practice:

1) Machine learning-based complication prediction models have demonstrated promising accuracy in retrospective validation studies and show potential for generating automated risk alerts; however, prospective clinical implementation evidence remains limited, and further nursing workflow integration studies are needed before routine bedside deployment. These models may enable nurses to prioritize high-risk patients for enhanced surveillance, but should not replace clinical judgment.

2) Deep learning-driven intraoperative imaging assessments provide objective perfusion data that could potentially inform postoperative monitoring priorities; nevertheless, no included study has yet demonstrated that AI-derived intraoperative findings directly alter nursing protocols or improve patient outcomes. Future research should evaluate whether intensified observation protocols guided by AI-detected suboptimal tissue perfusion translate into measurable nursing-sensitive outcome improvements.

3) Individualized risk prediction using electronic health records shifts nursing from routine fixed-point assessments to real-time intelligent early warning, supporting precision-tailored care such as targeted nutritional support or standardized escalation protocols for high-risk patients. Crucially, successful implementation requires addressing nursing-specific challenges: adequate training on interpreting AI predictions in clinical context, managing alert fatigue through appropriate threshold calibration, and ensuring nurses retain authority to override system recommendations when clinical circumstances warrant. AI systems must augment, not replace, nursing clinical judgment.

From the overall composition of the included literature, dedicated nursing informatics and translational implementation investigations are relatively scarce. Few papers comprehensively explore key practical barriers including insufficient model interpretability, incomplete seamless workflow integration between AI tools and daily nursing work, insufficient multi-center external validation of predictive algorithms, and long-term tracking of sustained patient-safety improvements brought by intelligent warning systems. Systematic research focusing on these practical bottlenecks remains an underdeveloped area within the current body of literature, which deserves focused exploration in follow-up nursing research to advance the clinical translation of postoperative AI early warning tools.

4.3. Predictive Three-Stage Nursing Implementation Framework

All hotspot, evolution and cooperation results from bibliometric analysis are objective statistical conclusions from included literature, which only describe the overall research landscape and cannot form actionable clinical nursing procedures.

Combining the field trends summarized by CiteSpace analysis, this study constructs a hypothesized three-stage predictive framework for AI early warning nursing after gastrointestinal tumor surgery. This staged model is a predictive inference put forward by the authors based on existing research, rather than direct output of bibliometric analysis. It divides postoperative care into three phases matching dynamic complication risks, with dedicated AI monitoring and nursing priorities for each period.

Phase 1 (0 - 24 h): Patients face high risks of hemorrhage and hemodynamic instability. High-sensitivity AI monitors vital signs and drainage data to support intensive nursing surveillance and avoid missed critical complications.

Phase 2 (24 - 72 h): Main risks are anastomotic leakage and thromboembolism. The AI system balances sensitivity and specificity to reduce false alerts; nurses interpret model outputs alongside patient conditions to deliver early mobilization, gradual feeding and wound care.

Phase 3 (>72 h to discharge): AI integrates long-term nursing data to screen patients with poor recovery or high readmission risk, and nurses develop targeted discharge and follow-up plans for high-risk groups.

This hypothesized predictive framework incorporates three core research directions identified via bibliometrics: machine learning prediction, EHR-based individualized risk stratification and nursing-integrated proactive AI warning. It also clarifies interdisciplinary roles: nurses interpret AI alerts, surgeons provide clinical decisions, and informatics staff optimize system parameters. The predictive model proposed in this paper offers a standardized, operable reference for clinical intelligent postoperative nursing.

4.4. Limitations

This study has four limitations. First, only WoSCC was retrieved, excluding nursing and Chinese databases, leading to selection bias. Second, English-only inclusion reduces global data representativeness. Third, mixed surgical and nursing content in literature causes thematic confusion in metadata-based analysis. Fourth, papers from late 2025 to 2026 lack full database indexing, possibly underestimating emerging frontiers. Nevertheless, WoSCC is a mainstream authoritative bibliometric database, and our conclusions objectively reveal the field's overall development trajectory.

5. Conclusions

This bibliometric visualization analysis systematically reveals that the research field of artificial intelligence applied in early warning nursing for gastrointestinal tumor postoperative complications is expanding rapidly and moving toward disciplinary maturity. The field has maintained exponential publication growth after 2021; China and the United States form the two core nodes of global research collaboration, while cross-national nursing academic communication still needs to be strengthened. Current research hotspots center on machine learning compli-

cation prediction models, deep learning intraoperative image auxiliary evaluation and individualized risk stratification based on electronic nursing records. The latest disciplinary frontier represented by risk prediction and prevention drives the transformation of traditional postoperative nursing to AI-enabled proactive predictive nursing.

Follow-up research should prioritize developing clinically verified, real-time intelligent early warning tools that can be seamlessly embedded into routine nursing workflows. Scholars need to pay more attention to model interpretability, multicenter external prospective nursing cohort verification, and interdisciplinary collaboration between artificial intelligence researchers, gastrointestinal surgeons and clinical nursing scientists. A series of targeted translational research will promote AI technology to evolve from laboratory research prototypes into practical clinical nursing tools, effectively improve the postoperative recovery quality of gastrointestinal tumor patients and continuously upgrade the standard of perioperative intelligent nursing services.

Ethics Statement

This study is a bibliometric analysis based exclusively on publicly available published literature. No human participants, animals, or identifiable private data were involved. Therefore, ethical approval and informed consent were not required.

Author Contributions

Conceptualization, W.Y.X. and H.W.L.; methodology, W.Y.X. and L.X.C.; software, W.Y.X.; validation, W.Y.X., L.X.C. and H.W.L.; formal analysis, W.Y.X.; investigation, W.Y.X. and L.X.C.; data curation, W.Y.X. and L.X.C.; visualization, W.Y.X.; writing—original draft preparation, W.Y.X.; writing—review and editing, L.X.C. and H.W.L.; supervision, H.W.L. All authors have read and agreed to the published version of the manuscript.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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