Present State and Recent Developments of Artificial Intelligence and Machine Learning in Gastric Cancer Diagnosis and Prognosis: A Systematic Review

Abstract

Objective:

The objective of this study is to thoroughly investigate the use of artificial intelligence (AI) and machine learning (ML) techniques for diagnosing and predicting prognosis in gastric cancer, utilizing the latest available data.

Methods:

Following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA)guidelines, a systematic review investigated AI and ML applications in gastric cancer diagnosis and prognostic prediction. PubMed and Google Scholar were searched from February 2019 to January 2024 using specific syntax. Eligible trials were selected based on inclusion criteria including recent publication, focus on AI and ML in gastric cancer, and reporting diagnostic or prognostic outcomes. Data were extracted and quality assessed independently, with discrepancies resolved through discussion. Due to design heterogeneity, detailed analysis was omitted, and descriptive summaries of included articles were provided.

Results:

This review included a total of 8 articles. AI and ML techniques, including convolutional neural networks (CNN) and deep learning models, have played pivotal roles in accurately diagnosing chronic atrophic gastritis, predicting postoperative gastric cancer prognosis, and identifying peritoneal metastasis in gastric cancer patients. These technologies offer potential advantages such as streamlining diagnostic procedures, guiding treatment decisions, and enhancing patient outcomes in gastric cancer management.

Conclusion:

In the near future, AI applications may have a significant role in the diagnosis and prognosis prediction of gastric cancer.

1. Introduction

Gastric cancer poses a persistent global health challenge, significantly impacting cancer-related morbidity and mortality worldwide (1). Despite advances in diagnostic and prognostic techniques, the demand for more precise, timely, and personalized approaches remains critical. However, the integration of Artificial Intelligence (AI) and Machine Learning (ML) technologies into clinical practice represents a promising frontier in oncology research, offering innovative solutions to enhance diagnostic precision and prognostic prediction (2). To comprehensively explore this research domain, this systematic review addresses a central inquiry: How do AI and ML applications impact the diagnosis and prognostication of gastric cancer compared to traditional methods, and what implications do they have for outcome precision? Through an examination of the relative effectiveness and accuracy of these technologies against conventional modalities, this review aims to guide clinical decision-making, stimulate further investigation, and ultimately enhance patient outcomes in the landscape of gastric cancer management.

2. Methods

2.1. Data Sources and Searches

We systematically reviewed clinical trials examining the effectiveness of artificial intelligence and machine learning in altering the outcomes for the diagnosis and prognostic prediction of gastric cancer. It was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. We searched PubMed and Google Scholar for articles that were published from February 2019 to January 2024 while using the syntax "artificial intelligence" OR "machine learning" AND "gastric cancer" AND "diagnosis" OR "prognostic prediction".

2.2. Study Selection

Initial screening of studies obtained by the syntax search in the literature database involved evaluating titles or abstracts to discern the paper's relevance. During this phase, trials eligible for inclusion were selected, and subsequently, the original papers were obtained for review. The selection of the trials was performed according to the following inclusion criteria: Studies published within the last five years; Research articles specifically focused on the application of Artificial Intelligence (AI) and Machine Learning (ML) in the context of gastric cancer; Studies reporting on diagnostic or prognostic outcomes related to gastric cancer. The explicit exclusion criteria were: Studies conducted before February 2019; Studies that do not address diagnostic or prognostic outcomes in the context of gastric cancer; Studies lacking sufficient methodological quality or a definitive conclusion statement.

2.3. Data Extraction and Quality Assessment

The studies were extracted manually and independently by the authors. Any discrepancies were resolved through discussion and reference to the original articles.

2.4. Data Synthesis and Analysis

Because of the considerable variation in design, conducting an analysis was inappropriate. Consequently, we provided descriptive summaries of the included articles using the table of evidence.

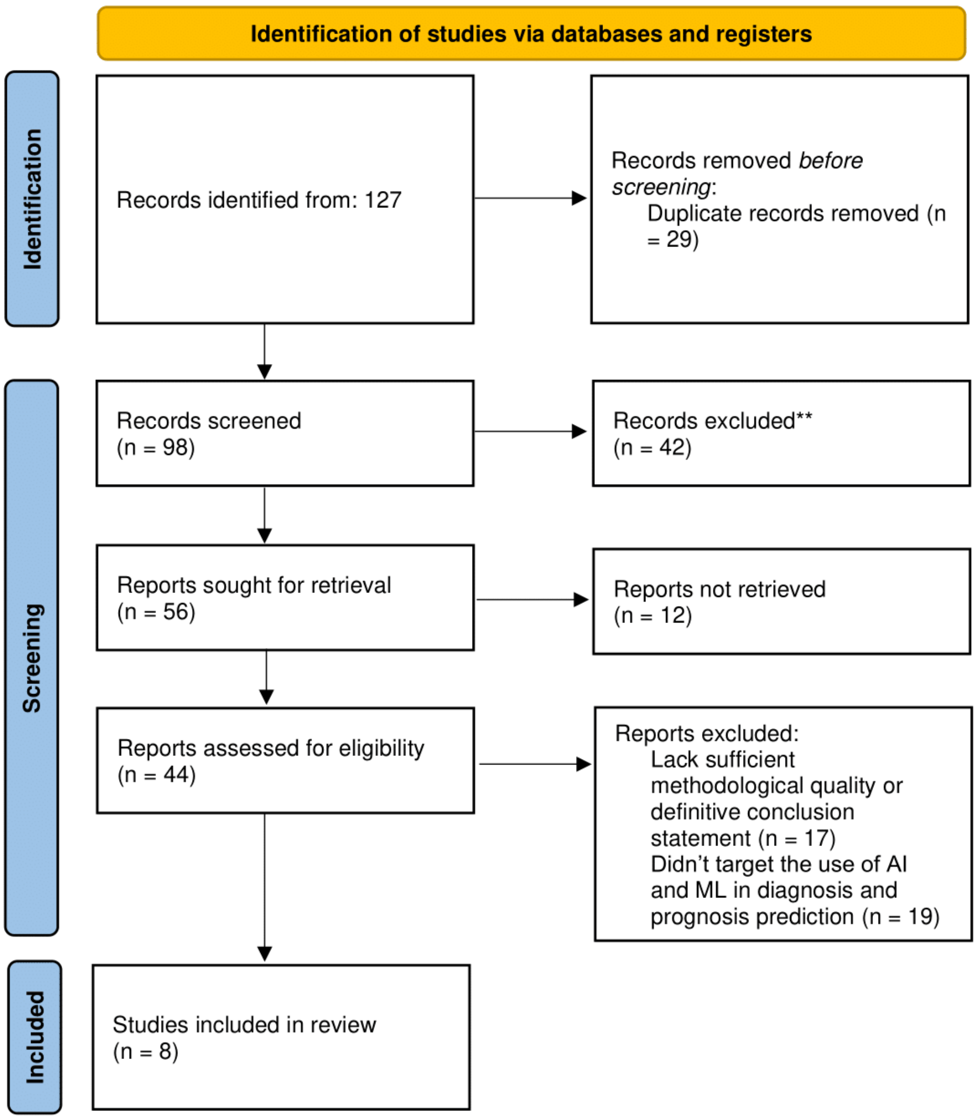
2.5. Ethical Considerations

The data from clinical trials doesn't involve any personal information. So, there is no need for the approval of the ethics committee.

3. Results

Initially, 127 titles were discovered; however, 29 duplicates were removed. 42 were excluded since they did not meet the previously stated inclusion criteria or met some of the exclusion criteria. After thoroughly reviewing these titles, 44 articles were selected to analyze the abstract. Ultimately, this systematic review included 8 articles to construct the role of AI and ML in gastric cancer diagnosis and prognostic prediction. The PRISMA flow chart (Fig 1) was made based on the above information.

Fig 1: PRISMA flow diagram



The results of the included studies are shown in Table 1.

Table 1: Studies included for systematic review

Author, year	Study Design	Participants	Intervention/Exposure	Outcomes	Results	Conclusion
Zhang Y et al. (2020). (3)	The study used a convolutional neural network (CNN) to construct a model for diagnosing chronic atrophic gastritis using gastroscopic images.	The study collected 5470 images of the gastric antrums of 1699 patients.	The use of gastroscopic images to diagnose chronic atrophic gastritis. The images were labeled with their pathological findings.	The outcomes of interest were the accuracy, sensitivity, and specificity of the CNN model in diagnosing atrophic gastritis. The study also evaluated the detection rates of different severity levels of atrophic gastritis.	The diagnostic accuracy, sensitivity, and specificity of the CNN model in diagnosing atrophic gastritis were 0.942, 0.945, and 0.940, respectively. The detection rates for mild, moderate, and severe atrophic gastritis were 93%, 95%, and 99%, respectively. The CNN model outperformed the diagnoses of three experts.	Chronic atrophic gastritis can be accurately diagnosed using gastroscopic images and a CNN model. The use of this model could reduce the burden on endoscopy physicians, simplify diagnostic routines, and reduce costs for doctors and patients.

Zhou C-M et al. (2023). (4)	The study used machine learning algorithms to predict postoperative gastric cancer prognosis based on inflammatory factors.	The participants of the study were patients with gastric cancer who underwent surgery.	The study applied six machine learning algorithms, including Gradient Boosting Machine (GBM), Logistic Regression (LR), and Extreme Gradient Boosting (Xgbc), to predict postoperative gastric cancer death.	The main outcome of interest was the prediction of total postoperative gastric cancer death.	The three most important factors for predicting postoperative gastric cancer death were found to be neutrophil-lymphocyte ratio (NLR), platelet lymphocyte ratio (PLR), and age. Logistic Regression (LR) had the highest accuracy (0.759), followed by the GBM algorithm (0.733). Among the six algorithms, GBM had the highest recall rate (recall = 0.667).	Postoperative mortality from gastric cancer can be predicted based on machine learning algorithms.

Zhou C et al. (2020). (5)	A Retrospective study design	The participants in this study were patients who had undergone gastric cancer surgery. The study included a total of 1080 patients with postoperative gastric cancer. They were divided into training and test groups in a 7:3 ratio.	The intervention/exposure in this study was the use of machine learning algorithms, specifically GBM (Light Gradient Boosting Machine), Gradient Boosting, forest, Logistic, and Decision Tree, to establish a model for predicting peritoneal metastasis of gastric cancer.	The main outcome of interest in this study was the prediction of peritoneal metastasis in patients with gastric cancer using machine learning algorithms.	The accuracy of the Gradient Boosting and GBM algorithms was the highest in the training group (0.909), while the accuracy of the forest, Decision Tree, and GBM algorithms was the highest in the test group (0.907). The AUC values ranged from highest to lowest as GBM (0.938), Gradient Boosting (0.861), forest (0.796), Logistic (0.741), and Decision Tree (0.712) in the training group, and as GBM (0.745), Gradient Boosting (0.725), forest (0.696), Logistic (0.680), and Decision Tree (0.657) in the test group.	Machine learning algorithms can be used to predict peritoneal metastasis in patients with gastric cancer

Huang B et al. (2021). (6)	Retrospective multicenter study using deep learning-based models to predict the diagnosis and overall survival of gastric cancer (GC) patients	1037 GC patients from Renmin Hospital of Wuhan University (RHWU) and the Cancer Genome Atlas (TCGA) cohorts. 91 GC patients from the National Human Genetic Resources Sharing Service Platform (NHGRP) were the independent external validation set.	Development involves two deep learning-based models: Gastrointestinal Malignancy Identification and Localization (GastroMIL) for diagnosing GC, and Malignancy Identification and Localization for Gastric Cancer (MIL-GC) for predicting the outcome of GC.	Diagnosis accuracy of GastroMIL in the external validation set. C-indices for survival prediction in the internal and external validation sets using MIL-GC. Risk score output by MIL-GC as a predictor of overall survival (OS) in univariate and multivariable analyses.	GastroMIL achieved an accuracy of 0.920 in the external validation set, surpassing the junior pathologist and comparable to expert pathologists. C-indices for survival prediction using MIL-GC were 0.671 and 0.657 in the internal and external validation sets, respectively. Risk score output by MIL-GC was a strong predictor of OS in both univariate (HR = 2.414, $P < 0.0001$) and multivariable (HR = 1.803, $P = 0.043$) analyses.	The study developed AI models for accurate diagnosis and prognosis prediction of GC, assisting in choosing appropriate treatment and improving the survival status of GC patients.

Liscia DS et al. (2022). (7)	The study used digital pathology and AI algorithms based on deep learning to diagnose Helicobacter pylori (HP) infections on low-magnification virtual slides.	The study's main outcome was to reliably diagnose HP infections using AI algorithms.	The use of digital pathology and AI algorithms for diagnosing HP infections on low-magnification virtual slides.	The study's main outcome was to reliably diagnose HP infections with whole slide imaging (WSI), even at a 20X magnification. The secondary outcome was to determine the accuracy of AI algorithms in diagnosing HP infections on digital pathology images.	The study found that the method used in the work accomplished the main goal of reliably diagnosing HP infections with WSI even at a 20X magnification.	AI algorithms hold greater accuracy in diagnosing HP infections on digital pathology images.

Li L et al. (2020). (8)	The study developed a new system based on convolutional neural network (CNN) to analyze gastric mucosal lesions	A total of 386 images of non-cancerous lesions and 1702 images of early gastric cancer were collected to train and establish the CNN model (Inception-v3). A total of 341 endoscopic images (171 non-cancerous lesions and 170 early gastric cancer) were selected to evaluate the diagnostic capabilities of the CNN and endoscopists	The use of the CNN system to analyze gastric mucosal lesions observed by Magnifying endoscopy with narrowband imaging (M-NBI).	The primary outcome measures included diagnostic accuracy, sensitivity, specificity, and positive and negative predictive values. It also evaluated the diagnostic capabilities of the CNN system and compared them with those of experts and non-experts.	The CNN system showed a sensitivity of 91.18%, specificity of 90.64%, and accuracy of 90.91% in the diagnosis of early gastric cancer. There was no significant difference in specificity and accuracy of diagnosis between the CNN system and experts. However, the diagnostic sensitivity of the CNN system was significantly higher than that of the experts.	The CNN system showed high accuracy, sensitivity, and specificity in diagnosing early gastric cancer based on M-NBI. It anticipates further progress in the optimization of the CNN diagnostic system and the development of artificial intelligence in the medical field.

Jin C et al. (2021). (9)	Retrospective analysis of preoperative CT images from patients who underwent gastrectomy with lymph node dissection at two medical centers.	Discovery cohort: 1172 patients. External validation cohort: 527 patients.	Deep learning system developed using preoperative CT images to predict lymph node metastases (LNMs) at 11 regional nodal stations in gastric cancer patients.	Prediction accuracy of LNMs at 11 nodal stations	Deep learning system demonstrated excellent prediction accuracy in the external validation cohort, with a median AUC of 0.876, sensitivity of 0.743, and specificity of 0.936 for 11 nodal stations. Imaging models outperformed clinicopathological variables for predicting LNMs.	The deep learning system can predict LNMs in gastric cancer, inform prognosis, and guide individualized surgical treatment.

Zhu Y et al. (2019). (10)	The study utilized endoscopic images of Gastric Cancer (GC) tumors to develop a Convolutional Neural Network Computer-Aided Detection (CNN-CAD) system. The CNN-CAD system was developed through transfer learning using a pre-trained CNN architecture, Residual Network 50 (ResNet50).	The study used endoscopic images of gastric cancer tumors obtained from patients at the Endoscopy Center of Zhongshan Hospital. A total of 790 images served as a development dataset and another 203 images as a test dataset.	The intervention/exposure in this study was using a CNN-CAD system to determine the invasion depth of gastric cancer based on endoscopic images.	The main outcome of interest was the accuracy and specificity of the CNN-CAD system in determining the invasion depth of gastric cancer.	The CNN-CAD system achieved a classification accuracy of 89.16%, sensitivity of 76.47%, and specificity of 95.56% in determining the invasion depth of gastric cancer. The CNN-CAD system had significantly higher accuracy and specificity compared to human endoscopists.	The CNN-CAD system could distinguish early gastric cancer from deeper submucosal invasion and minimize overestimating invasion depth, potentially reducing unnecessary gastrectomy.

4. Discussion

The collective findings underscore the transformative potential of artificial intelligence (AI) and machine learning (ML) in gastric cancer diagnosis and prognosis. Studies demonstrate the exceptional accuracy of AI models in diagnosing chronic atrophic gastritis, presenting a promising avenue for streamlining diagnostic procedures and reducing costs. Similarly, research highlights the predictive power of ML algorithms in forecasting postoperative outcomes and peritoneal metastasis, facilitating personalized treatment approaches. Furthermore, studies showcase the development of AI models for accurate diagnosis and prognosis prediction, potentially enhancing patient outcomes and treatment selection. Further, studies underscore the utility of AI in detecting gastric mucosal lesions and determining invasion depth, providing valuable insights for clinical decision-making. Collectively, these findings emphasize the pivotal role of AI and ML in revolutionizing gastric cancer management, promising improved diagnostic accuracy, prognostication, and personalized therapeutic interventions.

4.1. Identification of Chronic Gastritis and H. *pylori* Infection

Helicobacter pylori (HP) infection has the potential to trigger intestinal metaplasia and atrophic gastritis, leading to the development of gastric cancer (intestinal type) (11). However, conducting an endoscopic diagnosis is challenging and time-intensive. AI-supported endoscopic assessments, in comparison, have been documented to achieve high levels of sensitivity and specificity, even when utilizing standard endoscopic images. In a study, it was evident that AI algorithms exhibited superior accuracy in diagnosing HP infections on digital pathology images compared to traditional methods. This suggests promising prospects for integrating AI-driven diagnostic tools in pathology practices, particularly for identifying HP infections (7). Additionally, detecting chronic atrophic gastritis (CAG) at an early stage is essential to prevent the progression to gastric cancer. Chronic atrophic gastritis can be accurately diagnosed using gastroscopic images and a CNN model. The use of this model could reduce the burden on endoscopy physicians, simplify diagnostic routines, and reduce costs for doctors and patients (3).

4.2. Early Detection of Gastric Cancer

Gastric cancer ranks as one of the most prevalent forms of cancer globally and stands as the leading cause of cancer-linked deaths (12). While the 5-year survival rate for advanced gastric cancer ranges from 5% to 25%, it can soar to 90% for cases of Early Gastric Cancer (13). Although endoscopy has traditionally served as a primary method for gastric cancer screening, identifying EGC via imaging poses challenges due to subjective interpretations influenced by cognitive and technical variables (14). However, the CNN system showed high accuracy, sensitivity, and specificity in diagnosing early gastric cancer based on Magnifying endoscopy with narrowband imaging (M-NBI) (8). It anticipates further progress in optimizing the CNN diagnostic system and developing artificial intelligence in the medical field.

4.3. Prediction of Tumor Invasive Depth

Early Gastric Cancer is classified into T1a and T1b stages, indicating the tumor's penetration into the mucosa or submucosa (15). The primary approach for resection is endoscopic submucosal dissection (ESD) or endoscopic mucosal resection (EMR); otherwise, radical surgery becomes necessary. Treatment strategy and prognosis correlate with the depth of tumor invasion, which can be assessed using endoscopic ultrasound (EUS) as a common practice (16). Despite its widespread use, EUS has shown limited accuracy, around 70%, compared to conventional endoscopy (17). Consequently, accurately predicting invasion depth for EGC remains a significant clinical hurdle. In a recent development, Zhu et al. devised a convolutional neural network computer-aided detection (CNN-CAD) system for predicting invasion depth. The CNN-CAD system could distinguish early gastric cancer from deeper submucosal invasion and minimize overestimating invasion depth, potentially reducing unnecessary gastrectomy (10).

4.4. Metastasis and Stage Prediction

Anticipating the spread of cancer to lymph nodes (LNM) holds significant importance in guiding clinical decisions, such as selecting between endoscopic mucosal resection, neoadjuvant chemotherapy, or radical surgery (18). Presently, the conventional imaging methods for diagnosing LNM primarily rely on assessing lymph node size, shape, and density (19). Recently, utilizing deep learning systems has also led to improved interpretations aiding in the early detection of peritoneal metastasis (5). Additionally, the deep learning system can predict LNMs in gastric cancer, inform prognosis, and guide individualized surgical treatment (9).

4.5. Prognosis Prediction

Predicting the prognosis of gastric cancer (GC) has traditionally relied on various clinical and histopathological factors. However, with advancements in artificial intelligence (AI), particularly machine learning algorithms, the accuracy and reliability of prognosis prediction for GC have significantly improved. One notable aspect where AI has shown promise is in predicting postoperative mortality from gastric cancer (4). Moreover, recent studies have demonstrated the development of AI models tailored explicitly for gastric cancer diagnosis and prognosis prediction (6). The implementation of AI in prognosis prediction not only aids in selecting the most appropriate treatment approach but also contributes to enhancing the overall survival rates of gastric cancer patients.

4.6. Limitations and Future Research

In discussing the limitations of the evidence included in the review, it's essential to acknowledge certain constraints that may influence the interpretation and generalizability of the findings. While AI-supported diagnostic tools have shown promising results in the identification of chronic gastritis, H. pylori infection, early gastric cancer, and prediction of tumor invasive depth, the evidence primarily stems from observational studies and limited clinical trials. The variability in study designs, patient populations, and methodologies across the included studies may introduce bias and limit the strength of the conclusions drawn. Furthermore, the majority of the studies included in the review focused on single-center experiences, which may not fully capture the diversity of patient demographics, disease presentations, and healthcare settings. This could affect the external validity of the findings and their applicability to broader clinical contexts. Additionally, the reliance on retrospective data and small sample sizes in some studies may limit the robustness and generalizability of the results. Moreover, the inclusion and exclusion criteria applied during the screening process may inadvertently omit relevant studies, particularly those published in languages other than English or those indexed in databases not included in the search strategy. This could introduce selection bias and impact the comprehensiveness of the evidence synthesis.

Despite limitations, the review highlights AI's potential to enhance clinical practice for gastric cancer diagnosis and prognosis. AI-driven models offer a promising avenue for enhancing patient care and treatment selection. These advancements hold transformative implications for streamlining diagnostic procedures, reducing costs, and improving patient outcomes. Moving forward, future focus should prioritize the validation and optimization of AI-driven diagnostic and prognostic models across diverse clinical settings. Additionally, efforts should be directed towards addressing regulatory, ethical, and reimbursement concerns to facilitate the widespread adoption of AI in clinical practice, ultimately leading to more personalized and effective therapeutic interventions for gastric cancer patients. Longitudinal studies assessing AI's impact on clinical outcomes, patient satisfaction, and healthcare costs are necessary for informed decision-making and widespread adoption.

5. Conclusion

AI and machine learning have significantly advanced the diagnosis and prognosis prediction of gastric cancer. Through the analysis of complex data patterns and the integration of various medical imaging techniques, AI algorithms can now offer more accurate and timely assessments of gastric cancer, leading to improved patient outcomes and more personalized treatment approaches. This transformative impact underscores the potential of AI to revolutionize cancer care and emphasizes the importance of continued research and innovation in this rapidly evolving field.

Compliance with Ethical Standards:

Funding:
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Conflicts of interest:

The authors declare no conflict of interest. The authors have no relevant financial or non-financial interests to disclose.

Ethical approval:
This article does not contain any studies with human participants performed by any of the authors.

Informed consent:
Not applicable

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