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Automated Recognition of Abnormalities in Gastrointestinal Endoscopic Images – Evaluation of an AI Tool for Identifying Polyps and Other Irregularities

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Abstract

This study investigates the application of artificial intelligence (AI) for the automatic detection of pathological abnormalities in gastrointestinal endoscopic images. Specifically, it evaluates the performance of an AI tool in identifying and classifying lesions such as polyps and other irregularities, including inflammatory changes, within real-time endoscopic procedures. The primary objective is to assess the tool's diagnostic accuracy and its potential to improve lesion detection, thereby reducing the likelihood of overlooked abnormalities. Leveraging advanced machine learning techniques, particularly convolutional neural networks (CNNs), the AI system aims to enhance diagnostic precision and support clinicians in making prompt, evidence-based decisions. Key advantages of AI integration in endoscopy include improved sensitivity, minimized detection errors, and the potential to optimize clinical workflow efficiency. However, the study also addresses significant challenges, including the necessity for large, heterogeneous datasets for model validation, the need for standardized AI applications, and the ethical implications of AI-assisted clinical decision-making. Additionally, the potential benefits of combining AI with complementary imaging technologies, such as fluorescence imaging and spectroscopy, are explored to further enhance diagnostic capabilities. In conclusion, the study highlights the promising role of AI in gastrointestinal endoscopy while underscoring the importance of continued research, algorithmic refinement, and the establishment of regulatory frameworks to fully harness its clinical potential.

Keywords: Artificial Intelligence, endoscopy, gastrointestinal imaging, polyps detection, Computer-Aided Detection, Convolutional Neural Networks (CNNs), Predictive Analytics in Endoscopy, Machine Learning in Healthcare

1.1. Introduction

Endoscopic examinations play a pivotal role in both diagnostic imaging and the treatment of gastrointestinal disorders. Advances in modern technology have facilitated precise evaluation of internal organs, with a primary objective of identifying small yet clinically significant abnormalities, including preinvasive and early invasive neoplastic changes. Endoscopy not only enables the detection of pathological conditions such as ulcers, polyps, tumors, and inflammatory diseases but also serves as a platform for therapeutic interventions, including polyp resection, hemostasis, and stricture dilation. Due to its high precision and minimally invasive nature, endoscopy represents an indispensable tool in contemporary medical practice.

Despite its advantages, endoscopy presents several challenges for clinicians. The manual interpretation of endoscopic images is inherently complex and subject to various limitations that can affect diagnostic accuracy and therapeutic outcomes. A key issue is that image interpretation is highly dependent on the expertise and experience of the physician, leading to potential variability in diagnostic assessments among specialists [1]. Endoscopists also encounter difficulties related to spatial orientation, triangulation, and tissue retraction [5]. Additionally, variability in image quality [2] and the time-intensive nature of image analysis further complicate the process. The need to review and assess a large volume of endoscopic images demands significant time and concentration, increasing the likelihood of clinician fatigue and diagnostic errors [3]. Moreover, the inherent complexity of endoscopic images poses further challenges, as different pathological changes may exhibit similar visual characteristics, making accurate differentiation difficult [4]. Given the substantial data load and the often-subtle distinctions between pathological and normal findings, there is a considerable risk of overlooking critical abnormalities, particularly in the early stages of malignancies.

The integration of artificial intelligence (AI) and computer-aided diagnostic systems presents a promising solution to these challenges by enhancing diagnostic accuracy and mitigating the risk of human error. Technological advancements continue to improve the resolution and quality of endoscopic imaging, facilitating more precise detection and assessment of pathological changes within the gastrointestinal tract. The role of AI in medicine is expanding rapidly, offering significant potential to refine diagnostic methodologies and improve the early detection of gastrointestinal diseases.

This review aims to explore the applications of AI in the detection of pathological changes in endoscopic imaging, as well as its potential contributions to therapeutic decision-making and clinical management.

1.2. Aim of the study

The aim of this study is to evaluate the effectiveness and performance of an artificial intelligence (AI) tool in the automatic recognition of abnormalities in gastrointestinal endoscopic images. Specifically, the study seeks to assess the AI's ability to accurately identify and classify polyps and other pathological changes, such as inflammatory lesions, in real-time during endoscopic procedures. Additionally, the study aims to explore the potential clinical benefits of AI integration in enhancing diagnostic accuracy, improving detection rates, and reducing the likelihood of missed lesions in endoscopic examinations. The research further investigates the challenges and limitations associated with AI implementation in the clinical setting, including the need for model validation, standardization, and ethical considerations in AI-assisted diagnostics.

1.3. Materials and methods

For the purpose of this paper, electronic databases such as Scopus, Google Scholar, and PubMed were searched. A literature review was conducted using the following keywords: *Artificial Intelligence, endoscopy, gastrointestinal imaging, polyps detection, Computer-Aided Detection, Convolutional Neural Networks (CNNs), Predictive Analytics in Endoscopy, Machine Learning in Healthcare.* Original research studies, case reports, and review articles were utilized. The search was limited to publications in Polish and English.

2. Fundamentals of Endoscopy and Characteristics of Endoscopic Imaging

2.1. Endoscopy as a Diagnostic Modality

Endoscopy represents a cornerstone in contemporary clinical diagnostics, offering direct visual access to internal anatomical structures via minimally invasive means. Modern endoscopic systems, equipped with high-resolution optics, LED illumination, and integrated video technologies, facilitate real-time, high-fidelity evaluation of the mucosal architecture across various segments of the gastrointestinal tract [6]. The selection of an appropriate endoscopic technique is contingent upon both the anatomical location and the suspected pathological process. Gastroscopy and colonoscopy are routinely employed for the assessment of the upper and lower gastrointestinal tract, respectively, while enteroscopy and capsule endoscopy serve as essential modalities for the evaluation of small bowel disorders. Furthermore, endoscopic ultrasound (EUS), which combines traditional endoscopy with ultrasonographic imaging, permits detailed visualization of extraluminal structures [7].

In addition to its diagnostic utility, endoscopy is a pivotal therapeutic tool, enabling a range of interventional procedures including polypectomy, hemostasis, tissue ablation, and biopsy acquisition during a single session[8]. Parallel advancements in molecular imaging and optical enhancement techniques—such as autofluorescence imaging, narrow-band imaging (NBI), and confocal laser endomicroscopy—have substantially augmented the sensitivity and specificity of neoplastic lesion detection, facilitating earlier and more accurate clinical decision-making [9].

2.2. Characteristics of Endoscopic Imaging

High-resolution endoscopic imaging is integral to intraluminal diagnostics, as the precision and interpretability of the captured images are directly correlated with diagnostic accuracy. A broad array of imaging modalities has been developed, including white light imaging (WLI), narrow-band imaging (NBI), autofluorescence imaging, confocal endomicroscopy, and hyperspectral imaging (HSI). These modalities offer enhanced morphological and functional insight into mucosal and submucosal structures [7,10]. The deployment of high-definition endoscopic systems has markedly improved the visualization of subtle epithelial abnormalities, contributing to increased diagnostic sensitivity [11].
Image quality in endoscopy is modulated by multiple technical and procedural variables. Factors such as optical clarity, lens cleanliness, light source calibration, and color fidelity play essential roles [12]. Additionally, operator-induced motion artifacts, suboptimal positioning, inadequate luminal cleansing, and interference from medical instruments may introduce distortions that compromise image integrity and interpretability [13].

Artifacts in endoscopic imaging may originate from mechanical instability, optical interference (e.g., glare, fogging), or digital processing errors such as compression artifacts or signal degradation [14,15]. These distortions not only impair human visual interpretation but also hinder the performance of artificial intelligence (AI)-based diagnostic systems. Consequently, recent research has focused on developing robust computational strategies to detect and mitigate the influence of such artifacts, thereby preserving diagnostic fidelity. AI-assisted decision support tools are increasingly capable of distinguishing clinically relevant features from artifacts, thus enhancing interpretive accuracy—particularly in dynamic imaging contexts such as video endoscopy [16].

2.3. Common Gastrointestinal Abnormalities Identified via Endoscopy

Endoscopy affords unparalleled access to the gastrointestinal mucosa, enabling the detection of a wide range of pathological entities with high spatial resolution and temporal immediacy. Among the most frequently encountered abnormalities are polyps, mucosal erosions, ulcers, and neoplastic lesions. Adenomatous polyps, in particular, are recognized as precursor lesions in the adenoma–carcinoma sequence. Their identification and removal during colonoscopy significantly reduce the incidence of colorectal cancer [17]. In the stomach, hyperplastic and adenomatous polyps are commonly observed and may necessitate histopathological differentiation to assess malignant potential [18].
Ulcers and erosions, typically resulting from mucosal disruption, are often attributed to *Helicobacter pylori* infection, nonsteroidal anti-inflammatory drug (NSAID) use, or exposure to chemical and mechanical irritants. Endoscopic visualization facilitates differentiation: ulcers generally appear as deep mucosal defects with well-defined margins, whereas erosions tend to be more superficial with limited tissue destruction [19].
Neoplastic changes—including early-stage gastric and colorectal carcinomas—may manifest endoscopically as irregular surface topography, atypical vascular architecture, or disorganized epithelial patterns. The integration of deep learning models into endoscopic platforms has demonstrated high diagnostic accuracy in differentiating between benign and malignant lesions [20].

3. Artificial Intelligence in Endoscopic Image Analysis

3.1. Introduction to AI Methods in Medical Imaging

Artificial intelligence (AI) has become an essential tool in contemporary medicine, particularly in imaging diagnostics, where its applications are increasingly significant, especially in the field of endoscopy. AI-based systems are capable of automatically detecting, classifying, and analyzing pathological changes in endoscopic images. Given the substantial variability and visual complexity of endoscopic images, their interpretation presents a considerable challenge for physicians. In this context, AI serves as an auxiliary tool, functioning as a "digital assistant" during diagnostic procedures, thereby enhancing both the sensitivity and specificity of abnormality detection [21].

3.2. AI Models Utilized in Endoscopic Image Analysis

A variety of AI-driven methodologies are employed in the analysis of endoscopic images, which can be categorized into classical machine learning algorithms, deep learning models, and hybrid approaches.

Before the widespread adoption of deep learning, classical machine learning models, such as Support Vector Machines (SVM) and Random Forest, were commonly used in medical imaging. In these approaches, endoscopic images underwent manual preprocessing to extract key features—including texture, color, and edge shape. The extracted feature vectors were then utilized as input for an SVM classifier, which was tasked with differentiating between healthy and pathological tissue. For instance, SVM has been applied in the classification of colorectal lesions using narrow-band endoscopy images, where vascular patterns and surface structures were analyzed [22]. Despite the growing prominence of deep learning, SVM remains a valuable tool, particularly in scenarios where data availability is limited or in the development of hybrid models. The historical significance of these classical algorithms in the evolution of medical image classification underscores their continued relevance in specific clinical applications.

Recent advancements in AI have profoundly influenced endoscopic diagnostics, particularly through the implementation of convolutional neural networks (CNNs) and their advanced variants, such as ResNet and EfficientNet. These models have demonstrated significant efficacy in polyp detection, the classification of inflammatory changes in inflammatory bowel disease (IBD), and the identification of neoplastic lesions. A key advantage of CNNs lies in their ability to autonomously learn and extract relevant features from medical images, eliminating the need for manual preprocessing. This capability facilitates real-time detection and classification of pathological changes with high accuracy. AI-driven real-time diagnostic systems utilizing CNNs have been shown to reduce the time required for abnormality detection and decrease the rate of missed lesions by up to 50%. Studies on polyp detection have reported CNN sensitivity levels ranging from 94% to 98%[22, 23]. Additionally, CNNs have been successfully employed in the diagnosis of various gastrointestinal pathologies, including IBD [24], *Helicobacter pylori* infection [25], and gastrointestinal bleeding [26], achieving consistently high diagnostic performance.

Among the more advanced architectures, ResNet represents a deep neural network framework that incorporates residual connections, allowing for the effective training of very deep models without performance degradation. This architecture has been particularly effective in diagnostic tasks requiring high precision. Notably, ResNet has been applied in the detection of Barrett's esophagus-related neoplasia, demonstrating diagnostic performance comparable to, or even exceeding, that of expert endoscopists [23]. Similarly, ResNet has exhibited high sensitivity and specificity in the classification of gastric and small intestinal lesions, achieving results equivalent to those of experienced endoscopists.

EfficientNet, another state-of-the-art CNN architecture, has been designed to optimize performance and scalability. By employing a balanced approach to scaling network depth, width, and resolution, EfficientNet achieves superior predictive accuracy while maintaining lower computational demands. Its efficacy in gastric cancer detection and the analysis of colonoscopic images has been documented, with reported accuracy rates ranging from 96% to 98% [22]. Compared to earlier CNN architectures, EfficientNet demonstrates a superior balance between computational efficiency and diagnostic accuracy, making it a highly effective tool for the classification of neoplastic lesions [27].

The advancement of modern deep learning architectures has markedly improved the accuracy and efficiency of imaging-based diagnostics in endoscopy. CNNs, ResNet, and EfficientNet now serve as the cornerstone of AI-driven clinical decision-support systems, offering high diagnostic precision, real-time processing capabilities, and enhanced efficiency. The continued integration of these models into clinical practice holds significant potential for the earlier detection of malignancies and improved patient outcomes.

4. Effectiveness of AI in Detecting Polyps and Other Abnormalities

4.1. **Comparison of AI and Clinician Effectiveness in Endoscopic Diagnosis**

Artificial Intelligence (AI) has demonstrated comparable effectiveness to experienced endoscopists in the detection and classification of polyps within the context of endoscopic diagnostics, exhibiting high sensitivity but moderate specificity. Furthermore, a retrospective study involving data from 500 patients, 100 of whom had confirmed stomach cancer, found that AI-based examinations were not inferior in terms of stomach cancer detection. However, no evidence of superior performance was observed in comparison to traditional diagnostic methods[28][29].

4.2. **Challenges and Limitations in Detecting Abnormalities**

A significant challenge to the widespread implementation of AI in the detection of abnormalities during endoscopic examinations is the development and training of algorithms, which primarily rely on high-quality images from highly specialized reference centers[30]. In clinical practice, endoscopic images are often heterogeneous, varying in quality depending on clinical circumstances and the quality of the imaging equipment used. These variations in image quality are commonly referred to as the *domain shift problem*.[31] When this issue arises, AI algorithms may perform suboptimally, and their application may be less effective in smaller healthcare settings where the quality of images captured during routine examinations can be considerably lower. A study revealed a 12% difference in sensitivity and specificity when detecting abnormalities between high- and low-quality images[30].

4.3. **Adaptation of AI to Variable Clinical Conditions and Endoscopic Types**
In endoscopy, the quality of images is influenced not only by the experience and skill of the operator but also by the technical specifications of the equipment used. In addition, factors such as inadequate lighting, image blurring due to motion, and specific settings can significantly alter the quality and appearance of images, thereby creating a *domain gap*between high-quality images used to train AI models and those encountered in real-world clinical settings[32]. To address this challenge, strategies to enhance the robustness of AI models are employed. For instance, one study incorporated randomly selected frames from videos of the same patient cohort, which were of lower quality than the standard high-quality images used for model training. This approach helped improve the AI system's adaptability and performance in less-than-ideal conditions[30][32].

5. Practical Applications and Future of AI in Endoscopic Diagnostics

5.1. Real-Time Physician Assistance

The advancement of artificial intelligence (AI)-based systems has significantly transformed endoscopic diagnostics by providing real-time support to physicians. Advanced machine learning algorithms, including neural networks, enable rapid and precise detection of pathological changes, such as colorectal polyps, thereby enhancing the effectiveness of screening procedures [33]. Computer-aided detection (CADe) systems have demonstrated high sensitivity in real-time lesion identification, as confirmed by numerous clinical studies [34]. The integration of these technologies with modern endoscopic equipment allows for the immediate display of diagnostic recommendations on-screen, substantially reducing the risk of overlooking abnormalities [35].

5.2. AI Integration with Endoscopic Systems in Medical Facilities

The implementation of AI in medical institutions requires not only advanced hardware but also the adaptation of clinical procedures. Modern endoscopic systems are increasingly equipped with AI algorithms that facilitate early detection and classification of pathological changes, significantly improving diagnostic accuracy [36]. A notable example is the application of YOLOv8-based systems, which enable ultra-fast polyp detection with minimal latency, making them an ideal tool for real-time clinical applications [2]. Additionally, AI can be employed for patient data analysis and risk prediction of recurrent neoplastic lesions following polyp resection [5].

5.3. Future Technological Developments – Challenges and Opportunities for Further Optimization

Despite its numerous advantages, the integration of AI in endoscopy presents several challenges. One of the primary concerns is the need for AI model validation using large and diverse datasets, which is crucial for ensuring their efficacy and reliability in clinical practice [35]. Establishing standardized guidelines and regulations for AI applications in gastroenterology is a critical step toward widespread adoption [36]. Moreover, ethical considerations, such as accountability for diagnostic errors made by AI-driven systems, continue to require thorough discussion [33]. Further optimization of AI algorithms and their integration with other medical technologies—such as fluorescence imaging and spectroscopy—holds the potential to significantly enhance the efficiency of AI-assisted endoscopy in the future [37].

6. Discussion

The integration of artificial intelligence (AI) in endoscopic diagnostics represents a transformative advancement in medical imaging and clinical decision-making. The findings presented in this study highlight the significant role AI plays in enhancing diagnostic accuracy, reducing the likelihood of missed lesions, and improving the overall efficiency of endoscopic examinations. However, despite these advantages, the adoption of AI-driven technologies in gastroenterology also presents several challenges that must be addressed to ensure their widespread and ethical implementation.

One of the most compelling benefits of AI in endoscopy is its ability to support physicians in real-time during diagnostic procedures. The high sensitivity of AI-powered systems, such as convolutional neural networks (CNNs) and computer-aided detection (CADe) models, enables the rapid identification of pathological changes, including colorectal polyps and inflammatory lesions. The ability of these systems to provide immediate feedback directly on-screen reduces the likelihood of diagnostic oversights and enhances physician confidence. Studies have shown that AI-assisted detection can reduce the rate of missed lesions by up to 50%, demonstrating its clinical significance. Nevertheless, while AI improves sensitivity, its impact on specificity remains a subject of ongoing research, as false-positive detections may contribute to unnecessary interventions.

The successful integration of AI into clinical workflows requires not only technological advancements but also adjustments in hospital infrastructure and medical protocols. Modern endoscopic equipment is increasingly being equipped with AI capabilities, enabling automated lesion detection and classification. The use of AI models such as YOLOv8 for real-time polyp detection exemplifies the efficiency gains achievable with these systems. Additionally, AI-driven predictive analytics offer valuable insights into patient prognosis, such as assessing the risk of polyp recurrence following resection. However, the implementation of these technologies necessitates significant investment in high-performance computing infrastructure, staff training, and adaptation to existing healthcare regulations.

Despite the promising applications of AI in endoscopy, several challenges remain. One of the foremost issues is the need for rigorous validation of AI models using large and diverse datasets to ensure their generalizability across different patient populations. The variability of endoscopic images, influenced by factors such as lighting conditions, image resolution, and inter-patient anatomical differences, necessitates extensive training data to enhance model robustness. Additionally, standardization of AI applications in gastroenterology is essential to facilitate regulatory approvals and ensure compliance with ethical and legal frameworks. The absence of unified guidelines for AI deployment in endoscopy poses a potential barrier to its widespread clinical adoption.

Ethical concerns surrounding AI-driven diagnostics also warrant careful consideration. The issue of accountability in cases of misdiagnosis remains unresolved, raising questions about liability when AI-generated recommendations deviate from expert clinical judgment. While AI serves as an assistive tool rather than a replacement for physicians, the increasing reliance on automated decision-making underscores the importance of maintaining a balance between human expertise and machine intelligence. Addressing these ethical dilemmas through clear regulatory policies and transparent AI decision-making processes is critical to fostering trust in AI-assisted diagnostics.

Looking ahead, further optimization of AI algorithms and their integration with complementary imaging modalities, such as fluorescence imaging and spectroscopy, could enhance the diagnostic capabilities of endoscopic procedures. The combination of AI with these emerging technologies may offer new opportunities for early cancer detection and improved patient outcomes. Additionally, continued interdisciplinary collaboration between data scientists, gastroenterologists, and regulatory authorities will be instrumental in refining AI applications and ensuring their seamless incorporation into routine clinical practice.

In conclusion, while AI has demonstrated significant potential in advancing endoscopic diagnostics, its full realization necessitates overcoming technical, regulatory, and ethical challenges. Continued research, validation efforts, and policy development will be essential to unlocking the full benefits of AI in gastroenterology, ultimately contributing to improved patient care and clinical outcomes.

7. Conclusions

The findings of this study highlight the transformative impact of artificial intelligence in endoscopic diagnostics, demonstrating substantial improvements in lesion detection, diagnostic precision, and real-time clinical decision support. The integration of machine learning models, particularly convolutional neural networks, has significantly enhanced the accuracy and reliability of endoscopic evaluations, offering promising prospects for early disease detection and improved patient outcomes.

However, despite its evident advantages, the widespread adoption of AI in gastroenterology remains contingent upon overcoming several key challenges. The necessity for extensive validation on heterogeneous datasets, the standardization of AI applications, and the establishment of comprehensive regulatory frameworks are critical prerequisites for ensuring the safe and effective deployment of AI in clinical settings. Additionally, ethical considerations, particularly those related to accountability and trust in AI-driven diagnostics, further emphasize the importance of implementing clear policies and robust oversight mechanisms.

Future research should prioritize the optimization of AI models to enhance specificity, mitigate false-positive rates, and improve interpretability for clinicians. The integration of AI with advanced imaging modalities, such as fluorescence imaging and spectroscopy, presents opportunities to expand its diagnostic capabilities further. Furthermore, fostering interdisciplinary collaboration among medical professionals, AI researchers, and regulatory bodies will be essential in shaping the future landscape of AI-powered endoscopic diagnostics.

Ultimately, AI represents a pivotal advancement in medical imaging and gastroenterology, with the potential to revolutionize diagnostic accuracy and clinical efficiency. With continued research, technological refinement, and strategic implementation, AI-driven endoscopic systems can substantially enhance patient care and contribute to the ongoing evolution of modern medicine.

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