EDITORIAL

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Artificial Intelligence in Gastroenterology - Promises and Limits

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Artificial intelligence (AI) has origins dating back to the mid-20th century and is now playing a central and growing role in most medical specialties, including digestive diseases [1]. Artificial intelligence refers to a field of computer science that was finalized to create software capable of realizing performances that are exclusive results of human intelligence. These skills include, for example, the ability to solve problems through deductive logic and the ability to draw conclusions based on visual or auditory sensory input. The term "AI", although widely used today, originated in the same years as computer science, with its first mention in 1956 by Professor John McCarthy from Stanford University [2]. The first applications of AI in the healthcare sector date back to the 1970s, when the first computational algorithms to support decisions were developed in clinics and computerized health data were analyzed [3]. In recent years, AI has experienced renewed interest due to the growing availability of digital data and the evolution of the computing capabilities of information technologies. "Data mining" and "machine learning" (ML) are terms that are used more frequently in everyday life; they allow computers to extract significant information from large data and learn autonomously from it without the need for programming specifications [4]. Deep learning (DL) represents an evolution of these techniques, exploiting artificial neural networks inspired by the functioning of the human brain. The advantage of DL is the ability to process data in different formats, such as video and audio, without predefined labels, progressively learning in an increasingly autonomous way [5].

However, the integration of AI in healthcare also brings ethical and legal challenges that the industry must be aware of and prepared to address. The well-known concept of "evidence-based medicine" refers to the approach to medical practice using the best scientific evidence available to make clinical decisions. Medical AI follows a similar approach; it trained through ML with a wide range of medical data to improve clinical decision-making and healthcare in general [6]. In the past, statistical methods addressed this challenge by trying to describe present patterns in the data through mathematical equations. For example, traditional statistical analysis, such as linear regression, attempted to identify a "line of best fit" to the data. However, with the advent of ML, AI offers different approaches. Machine learning techniques allow you to discover complex relationships between the data, i.e., relationships that often cannot be easily reduced to a simple mathematical equation. A concrete example is neural networks, a model that, like the human brain, represents data through a vast number of "neurons" interconnected. This configuration allows ML systems to solve complex problems like the human mind by carefully evaluating available evidence to reach reasoned conclusions. However, unlike a single physician, these systems can simultaneously and quickly process almost unlimited input data [7]. Any system can learn from each new case it faces and take into consideration a much larger amount of recorded data, all in a few minutes. Therefore, AI-based applications can provide, for example, more accurate classifications of suspicious skin lesions compared to those dermatologists that would have identified without this support [8].

Artificial intelligence in healthcare encompasses multiple fields and describes the application of ML processes and other cognitive technologies in the clinical context. It is fundamentally based on data, and the training phase is a crucial aspect of all AI models [9]. Training of the models falls into three major classes: (i) supervised learning, which uses labeled data to train models for specific tasks such as classification and regression; (ii) unsupervised learning, which deals with unlabeled data, finding hidden patterns or intrinsic structures within the data, and it is useful for exploratory data analysis and clustering; (iii) reinforcement learning which focuses on training agents through trial and error, using feedback from actions to learn optimal behaviors. It is particularly suited for sequential decision-making tasks, and supervised learning may predict the presence of diseases such as colorectal cancer from endoscopic images, identify and delineate organs and abnormal growths in medical images, or forecast disease progression based on historical patient data [9]. Unsupervised learning may be used to identify unusual patterns in patient data that could indicate rare diseases or group patients with similar symptoms or disease profiles to tailor treatment plans. Finally, unsupervised learning may be used to train robotic systems to perform precise surgical tasks with optimal efficiency and safety. This phase involves collecting large datasets, the foundation for the AI‘s learning process. Such training data includes examples and features relevant to the task the AI is designed to perform; for instance, an AI model for recognizing cancers from colon images would require thousands of labeled images (data) to learn how to distinguish cancer from non-cancer tissues. The more data AI has, the better it can identify subtle patterns and improve accuracy [10]. Moreover, input data should be preprocessed to reduce the noise that may lower the overall accuracy of the trained models. After the iterative training process, novel data, also called validation and test sets, are used to evaluate the model‘s performance to ensure the model‘s generalization. After these steps, the AI model, with its ability to support clinician decisions, could be deployed, empowering healthcare professionals with advanced tools. Continuous data collection also helps refine and update AI models, making them more effective over time [11]. Thanks to novel biomedical technologies, data is increasingly available to train AI algorithms to perform analyses.

Specifically, in gastroenterology, AI is applied to increase the diagnosis and predict the treatment responses for a spectrum of conditions, such as malignant and premalignant lesions, inflammatory lesions, small bowel bleeding, and pancreato-biliary disorders [12]. Also, in the domain of hepatology, AI techniques could be used to reduce the risk of liver fibrosis evolution and to allow patients to avoid liver biopsy. In particular, supported by continuous learning, AI allows a more accurate endoscopic examination of both the lower and upper digestive tract than in the past, detecting the presence of tumors or vascular lesions, which, otherwise, even expert operators might miss viewing for several reasons. Also, the improved precision of the investigations supported by AI allows physicians to characterize the founded lesions better and promptly identify those worthies of analysis [11]. Studies reported in the literature on the use of AI in association with capsule video endoscopy report that for faster reading of films studying the small intestine, searching in this long stretch for the presence of ulcers, vascular lesions, or cancers potentially responsible for bleeding that cannot otherwise be documented with endoscopy [13]. There is no difference for the patient who undergoes this new diagnostic test compared to a classic colonoscopy. On the contrary, for the gastroenterologist, the difference is notable thanks to the reception of visual and audible warnings on the presence of lesions that would be difficult to diagnose without specific equipment. This application is relevant since detecting more lesions during colonoscopy reduces the risk of delay in colon-rectal cancer detection. Even in gastroenterology, imaging techniques that use radioisotopes or require large economic resources and the relatively low incidence of some pathologies are limiting factors for acquiring data.

Artificial intelligence techniques may support the process of synthetic image generation to create images that replicate real-world scenarios [12]. Algorithms can produce synthetic images that enhance specific features in medical scans, such as CT or MRI images. This makes identifying and diagnosing conditions such as tumors, polyps, or inflammatory diseases easier. Synthetic images play a crucial role in training AI models, as these models require large datasets to identify and classify different gastrointestinal conditions accurately. Synthetic data can complement real data by providing diverse examples, thereby improving the accuracy and robustness of the model. Surgeons can utilize synthetic images to simulate and plan complex surgical procedures. These simulations help them understand the spatial relationships between different structures in the gastrointestinal tract, predict potential challenges, and improve surgical outcomes. Synthetic images can be used to create personalized 3D models of a patient‘s gastrointestinal anatomy, assisting in planning treatments tailored to the individual‘s unique anatomy and leading to more precise and effective interventions. However, despite the potential role of AI in diagnostic endoscopy, clinical outcomes and specific guidelines to apply in real-life scenarios remain to be established.

On the other hand, the problem of the sustainability of the costs of these practices and adequate training of operators remains open [14]. Training projects that involve specialists and primary care doctors must be developed to treat digestive system diseases more effectively and sustainably. The importance of these training projects cannot be overstated, as they play a crucial role in shaping the future of AI in healthcare. More recently, large language models such as GPT, often coupled to retrieval augmented systems, enable the automatic extraction of useful information from the corpora of electronic health records by reusing existing information in retrospective studies [15].

Also, using AI in clinical practice opens ethical and legal challenges due to data privacy and security, safety, reliability, fairness, transparency, and accountability [16]. The extent of reliance on AI for decision-making is a crucial consideration, given that the final responsibility is ever in the charge of the physician. Artificial intelligence has the potential for bias in clinical problem selection, variable choices, algorithm development, and system use. In gastroenterology, as in other fields, training sets must be inclusive and diverse to avoid bias in diagnosing diseases with varying prevalence rates. As healthcare professionals, the audience is significant in ensuring these training sets are diverse and inclusive [17, 18]. Health equity goals should be incorporated early in algorithm development to mitigate potential biases by involving technically diverse research teams.

The perspectives are that AI will significantly improve clinical practice in gastroenterology, particularly from image interpretation to decision-making [19-23]. Despite these advantages, integrating AI into clinical practice is challenging. One significant hurdle is the interpretability of AI models, often called the "black box" problem [24-28]. Many AI algorithms, particularly those based on DL, make decisions based on complex patterns in the data that are not easily understandable by human clinicians. This lack of transparency can make it difficult for healthcare providers to trust AI-based recommendations, especially in critical or life-threatening situations. Moreover, another concern is the robustness of AI models when exposed to real-world data that may differ from the data used during training. Ensuring that AI systems perform consistently across diverse patient populations and clinical settings is critical to widespread adoption [29-33].

In gastroenterology, where real-time decision-making is often required, the latency of AI models - how quickly they can process data and provide output - also becomes an important factor. This is particularly relevant in procedures such as endoscopy, where the ability to analyze real-time video feeds and alert clinicians to abnormalities is crucial. Developing efficient algorithms that can operate within these time constraints without compromising accuracy is an ongoing area of research [34, 35].

Furthermore, implementing AI in healthcare raises significant ethical and legal questions. Patient consent, data ownership, and the right to privacy are paramount, especially when dealing with sensitive health information. The use of AI systems also introduces questions of liability - if an AI system makes a diagnostic error, it is unclear who would be held responsible: the software developers, the healthcare providers, or the institution that deployed the AI. These ethical considerations require careful navigation to ensure that AI enhances healthcare delivery without compromising patient rights or safety [36, 37]. Finally, the cost-effectiveness of AI applications in gastroenterology remains to be fully demonstrated. While AI can potentially improve diagnostic accuracy and patient outcomes, the high cost of developing, implementing, and maintaining these systems could be a barrier for many healthcare facilities, particularly in resource-limited settings. Cost-benefit analyses and studies on the long-term economic impact of AI in gastroenterology will be necessary to justify its adoption on a larger scale [38,39].

In conclusion, AI is poised to revolutionize the field of gastroenterology, offering significant improvements in diagnostic precision, treatment planning, and patient management. However, its integration into clinical practice must be approached with careful consideration of the associated technical, ethical, and economic challenges [40]. Ongoing research, interdisciplinary collaboration, and robust clinical trials will be essential in realizing the full potential of AI in this field, ensuring that it is deployed in a way that is both effective and equitable.

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