Artificial Intelligence in

Cancer

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Artificial Intelligence in Cancer

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ABOUT COVER

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AIMS AND SCOPE

The primary aim of *Artificial Intelligence in Cancer* (*AIC, Artif Intell Cancer*) is to provide scholars and readers from various fields of artificial intelligence in cancer with a platform to publish high-quality basic and clinical research articles and communicate their research findings online.

AIC mainly publishes articles reporting research results obtained in the field of artificial intelligence in cancer and covering a wide range of topics, including artificial intelligence in bone oncology, breast cancer, gastrointestinal cancer, genitourinary cancer, gynecological cancer, head and neck cancer, hematologic malignancy, lung cancer, lymphoma and myeloma, pediatric oncology, and urologic oncology.

INDEXING/ABSTRACTING

There is currently no indexing.

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MINIREVIEWS

Potential and role of artificial intelligence in current medical healthcare

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Abstract

Artificial intelligence (AI) is defined as the digital computer or computer-controlled robot's ability to mimic intelligent conduct and crucial thinking commonly associated with intelligent beings. The application of AI technology and machine learning in medicine have allowed medical practitioners to provide patients with better quality of services; and current advancements have led to a dramatic change in the healthcare system. However, many efficient applications are still in their initial stages, which need further evaluations to improve and develop these applications. Clinicians must recognize and acclimate themselves with the developments in AI technology to improve their delivery of healthcare services; but for this to be possible, a significant revision of medical education is needed to provide future leaders with the required competencies. This article reviews the potential and limitations of AI in healthcare, as well as the current medical application trends including healthcare administration, clinical decision assistance, patient health monitoring, healthcare resource allocation, medical research, and public health policy development. Also, future possibilities for further clinical and scientific practice were also summarized.

Core Tip: In this review, we explored the potential of powerful artificial intelligence (AI) for a more comprehensive application in the healthcare setting. Moreover, we also pointed out the demerits and problems in the current application of AI in medicine.

INTRODUCTION

McCarthy, one of the core founders of artificial intelligence (AI), defined AI as the science and engineering of making intelligent machines[1]. AI has come a long way since its conception in 1956[2]. AI research aims to establish a capable system with intelligence to overcome the Turing test, demonstrating intelligent behavior identical to humans. For the next 60 years, this specialty encountered several episodes of excitement and frustration with nearly no advancement. However, in 2010, deep learning achieved marked improvements. This achievement is a type of machine learning (ML) with multiple layers of nodes among the input and output layers, resulting in artificial neural networks capable of establishing excellent development in recognizing speech, classifying an image, and translating context[3].

AI has been applied to analyze complex and big data to deliver outputs beyond human input in diverse healthcare backgrounds[4]. Davenport *et al*[5] advocated that AI systems would not extensively take over human clinical professionals but would amplify their patient care achievements. In other words, the concept of professional advice from a digital helper is not better than the clinician, but the fusion and application of ML into clinical medicine would enhance accurate healthcare delivery[6]. Rather than traditional robotics, AI applications in current healthcare mainly affect clinicians and medical institutions accessing enormous data sets of crucial clinical knowledge. A scheme of medical information for patient care could use sophisticated algorithms to give real-time analysis[7], including diagnosis, management strategies and prognosis, recurrence and survival rates, and information collection rates of millions of patients, geographical distributions, and countless and sometimes interconnected health status of oncologic patients. This advanced computing power of AI can detect and analyze large and small trends from the available information, and even forecast through ML designed to classify possible health prognoses.

The importance of AI technology in medical healthcare provision and study is increasingly becoming apparent[8]. There is a rapid growth trend of related publications on this topic in the form of academic articles from medical professionals (Figure 1). Specialists have emphasized the effectiveness and
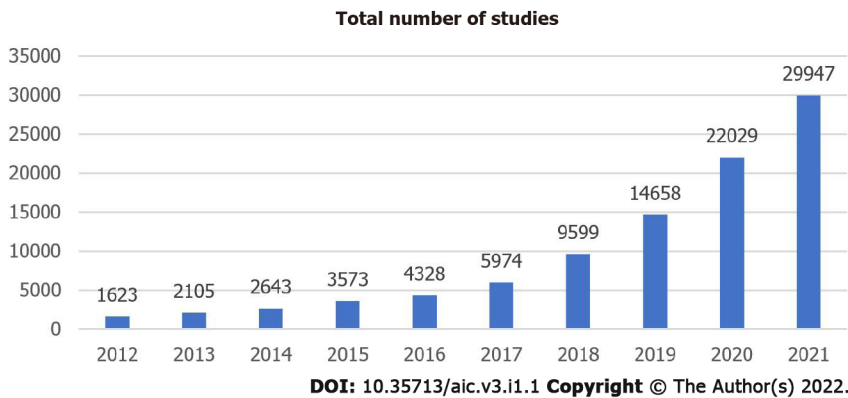
Total number of studies

Figure 1 Number of medical artificial intelligence publications by year beginning in 2012 up to 2021, searched on Pubmed.com using the terms "machine learning" OR "deep learning".

capability of AI-empowered healthcare provision. Recently, more countries and private institutions have invested in this technological progress[9]. In addition, the United States Food and Drug Administration (FDA) has enthusiastically promoted AI-empowered instruments in the medical market[10].

In this study, the potentials of AI, its application in different fields of healthcare, and its current limitations will be discussed. Furthermore, we also investigated the advantages of clinicians over AI in clinical work and suggest different ways of cooperating with AI effectively.

RELEVANT POTENTIALS OF AI

AI is a collection of technologies consisting of abilities that could be applied in healthcare. Some particular AI technologies are paramount to healthcare (Figure 2).

Neural network and deep learning

Neural networks and deep learning are essential to ML, a statistical technology for fitting models to data and 'learning' by training models with data. The neural networks technology has been available since the 1960s for categorization applications[11]. A standard neural network comprises many simple, connected processors called neurons, each producing a sequence of real-valued activations[12]. It imitates the process of how neurons manage signals. It can determine if one person would suffer from a specific disease in his or her life. It views the disease based on the inputs, outputs, and weights of variables or parameters related to the inputs with outputs.

Deep learning is the most complicated form of ML, which involves neural network models with different levels of parameters to predict prognosis. Each character in a deep learning model usually has limited implications for clinical professionals. In other words, the explanation of the model's prognosis may be very challenging to interpret. Nowadays, the typical utilization of deep learning in healthcare involves the recognition of possibly cancerous lesions in radiologic imaging[13]. Currently, it is commonly applied to detect clinically specific features in imaging data, which is easily neglected by the human eye[14].

Natural language processing

Since the 1950s, AI researchers have strived to make sense of human language. Natural language processing aims to program machines to interpret human language as humans do. It comprises speech recognition, word analysis, sentence translation, and other intentions based on human language. Statistical natural language processing is related to deep learning neural networks. It has also contributed to increased recognition accuracy. A natural language processing system can duplicate patient interactions and operate conversational AI[15]. Furthermore, it has succeeded in scaling up partial roles of clinical decision-making, developing tools to stratify risks, and even identifying possible surgical complications from clinical records[16], and performing patient triage by identifying syndromes[17].

Rule-based expert systems

Expert systems could automatically alert patients and provide instructions according to the telemonitoring data. This is expected to increase patient self-care and improve clinical management[18].

In the 1980s, expert systems related to the 'if-then' rules were the primary technique for AI. Human experts and knowledge engineers were required to build up a set of guides in a specific knowledge domain. In the healthcare aspect, they were extensively applied to assist in making clinical decisions.
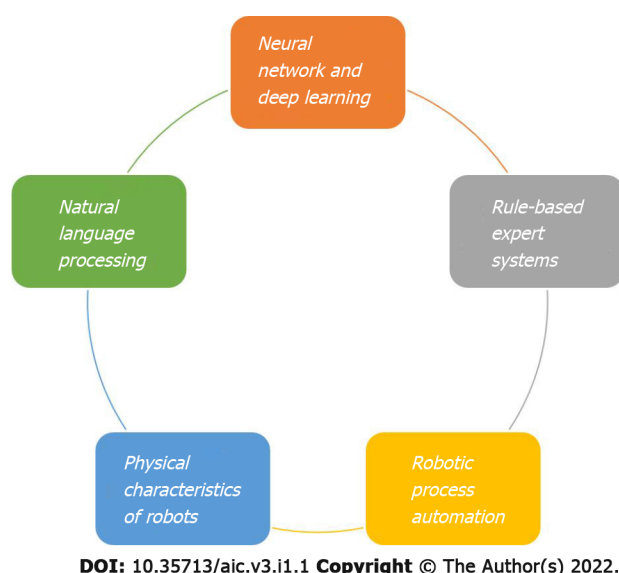
Figure 2 Relevant potentials of artificial intelligence.

This system consisted of an expert system and a statistical analysis system linked to a patient database [19]. They have been used for the past decades, but are more extensively used nowadays[20]. However, they are proposed to be replaced by more advanced ML algorithms, possibly because of their static nature. As these expert systems are applied to clinical use, this demerit becomes accentuated by the rapid generation rate of new knowledge, the regional differences related to the expression of many diseases, and the change rate of patient demographics and disease incidence in the future[19].

Physical characteristics of robots

Physical robots are well-known for performing repetitive and precise pre-defined work, such as elevating, locating, welding, or collecting objects during hospital supply delivery. Since the 1980s, there has been an incremental development of minimally invasive surgeries. However, this was limited by the complexity of surgery due to the technical constraint of traditional laparoscopic instruments. Robotic technology provides a 3-dimensional view of the operating field, allows filtering of physiological tremor, and permits greater precision and control through its articulated arms. These advantages offer solutions to the limitation of traditional laparoscopic instruments[21]. The United States initially approved robot-assisted surgery in 2000. Robots empower the surgeons and provide a clearer vision to perform accurate and minimally invasive surgery resulting in smaller surgical wounds[22]. Robotic-assisted prostatectomy, cystectomy, pyeloplasty, nephrectomy, and partial nephrectomy are all becoming increasingly common techniques used by surgeons[23]. Moreover, robots are becoming more intelligent, as other AI facilities are being installed in the operating systems. Of course, dominant decision-making is still made by humans during surgery.

Robotic process automation

"Automation" is defined as the application of robotics, AI, ML, machine vision, and similar emerging and mature digital technologies to allow human work to be substituted by robots[24]. This technique executes structured digital works for organizational goals. Robotic process automation involves mere computer programs on servers. It hinges on a set of work assignments, business guidelines, and a 'presentation layer' combination with information systems to mimic a semi-intelligent system operator. In the medical field, it is usually applied to perform repetitive work, *e.g.*, updating patient records or billing, extracting data from images into transactional systems, *etc*[25].

According to the study by Willis *et al*[26], many forms of automation already exist in the healthcare setting. Not only do they increase the productivity of human employees, but they also do not remove human tasks entirely. Automation has even unexpectedly created more work for the medical staff. Although automation has allowed humans to process tasks more efficiently, it has resulted in more administrative work.

PRACTICAL FIELDS OF AI APPLICATION IN HEALTHCARE

During the global health emergency related to coronavirus disease 19 (COVID-19), experts have worked day and night to explore new technologies to mitigate the pandemic. Due to this, the trend of AI

Healthcare administration

Performs repetitive and routine work, *e.g.* data entry, imaging, and laboratory data review

Time-saving, more accurate

Clinical decision assistance

Provides decision-making assistance through computer-guided programs, based on patient clinical data and updated knowledge

Lowers medical error rate, improving healthcare consistency and efficacy

Patient health monitor

New access to digital data transfer to medical institutions or patient individual

Monitors patient health status, allowing them to stay connected with health caregivers to provide emergency alert or first aid when needed

Healthcare resource allocation

Assists in planning medical resource allocation and providing social care

More precision in connecting individual patients with suitable and in-time healthcare providers or medical treatment

Medical research

Performs rare and exceptional case analyses from large and complex databases to aid medical progress

Transforms the critical steps in clinical trial design, from study preparation to execution, to improve the trial success rates

Saves time
More precise
Lowers cost burden of research units

Public health policy development

Uses big data analytic methods to assist in public health policy development

Allows early detection of infectious disease outbreaks and sources of epidemics

Provides forecasts for adverse drug reactions

Figure 3 Practical fields of artificial intelligence application in healthcare.

application in healthcare has grown rapidly[9], and has involved the development of sophisticated algorithms to perform complicated work efficiently and effectively[27]. Recent research has shown that AI could greatly enhance COVID-19 screening, diagnostics, and prediction, resulting in better scale-up, a timely response, a more reliable and efficient outcome. Furthermore, it was found that sometimes it outperforms humans in certain healthcare tasks[28].

In summary, AI-empowered healthcare delivery exerts a significant impact on healthcare administration, clinical decision assistance, patient health monitoring, healthcare resource allocation, medical research, and public health policy development (Figure 3).

Healthcare administration
AI could save time, which the clinical staff could use to care for patients, by performing repetitive and routine work, such as data entry, imaging, and laboratory data review[2]. The connection of ML algorithms with digital medical records could help clinical staff and administrators gain accurate patient data[29]. The accuracy and speed of data searches could be refined using ML and concept-based information retrieval systems. AI has already been applied to identify diseases even in the early stages. For example, AI-assisted diagnosis of breast cancer has significant advantages over those without AI assistance. It helps radiologists act as a second interpreter during data interpretation and patient screening. According to the American Cancer Society, it also reduces false-positive diagnosis rates, eliminating the need for unnecessary biopsy and lowering medical expenses[30]. It can finish reviewing and reporting the findings in just a few seconds. Although innovative methods have been established to diagnose and distinguish breast cancer, none of those methods could identify all cancer patients.

Clinical decision assistance
Clinical decision assistance systems are computer-guided programs that assist clinicians in their decision-making based on patient clinical data and updated knowledge[31]. AI is a powerful tool that lowers the medical error rate and improves healthcare consistency and efficacy.

The trend of AI application in clinical decision assistance is rising tremendously. For example, the case number of the COVID-19 global pandemic has overcome current medical facilities and obligated the clinical professionals, patients, and families to make crucial determinations based on limited information and within a short time. ML methods have been previously applied to assist in making clinical decisions. There is currently a demand for ML-supported decisions based on acquired vital signs, laboratory data, prescription orders, and complications from caring for previous patients. In clinical practice, AI-related precision medicine can predict patients' most suitable treatment protocols based on different patient characteristics and the treatment context[32]. AI can also make individualized treatment protocols for patients based on the large-scale database and updated information[33]. In addition, it is expected to guide inexperienced hospital frontline and healthcare providers to perform

appropriately with ample evidence under emergent situations[34].

Patient health monitoring

The popularity of smartphones and monitoring instruments has brought new access to digital data transfer to medical institutions. Using digital medical records also empowers the AI to monitor patient health status[29]. Through AI, patients with chronic diseases could be better informed about their health and stay connected with their health caregivers. Furthermore, AI-assisted home health monitoring instruments and techniques help low functioning and elderly patients to keep connected to assure that emergency medical technicians can immediately provide first aid when needed[35].

AI systems are also capable of following patient prognosis. For example, the National Institutes of Health has created the AiCure app to monitor medication used by patients. Moreover, those with hypertension or diabetes could benefit from AI's ability to track their health status through its clinically validated sensors and devices, effectively driving self-management[35]. Technology applications and apps boost more suitable actions in individuals and push one to follow a healthier lifestyle. In other words, it puts people in control of their health and well-being.

Healthcare resource allocation

Many governments use AI to plan medical resource allocation and provide social care services. AI could connect individual patients with suitable healthcare providers who could satisfy their needs based on their allocated medical budget.

Furthermore, AI could also design a specific treatment protocol and suggest more effective resource use for every patient[36]. For example, clinicians could identify potential risk factors associated with obesity using statistics, ML, and data visualization methods. AI systems can generate automated, personalized, contextual, and behavioral recommendations for obese patients during body weight control, including the suggestion of bariatric surgery, if indicated[37].

Shi *et al*[38] and Shi *et al*[39] used an artificial neural network model for predicting the 5-year mortality after surgery for hepatocellular carcinoma using the administrative claims data obtained from the Taiwan Bureau of National Health Insurance (BNHI). Their studies demonstrated that surgeon volume was the most crucial factor influencing 5-year mortality, followed by hospital volume and Charlson co-morbidity index. These parameters could be addressed in preoperative and postoperative healthcare consultations to educate the patients for better recovery and prognosis after hepatocellular carcinoma surgery. In addition, the government could also adjust the policy of healthcare resource allocation in hepatocellular carcinoma surgery with the aid of the AI-empowered analysis results of the BNHI database.

Medical research

Clinicians could use AI to analyze rare and exceptional cases from large and complex databases faster and more precisely than previously[40]. AI could also search for related scientific studies and information from the literature and combine different data to aid in medical progress[41]. In clinical trials, inappropriate patient selection and recruiting techniques, paired with ineffective patient monitoring and coaching could lead to high trial failure rates. AI can transform the critical steps of a clinical trial design, from study preparation to execution, to improve the trial success rates, thus lowering the cost burden of the research units[42]. It is expected to select the most precise patient data for relevant clinical studies and establish a database with a large population for more studies in the future.

Kiely *et al*[43] applied real-world data to screen for idiopathic pulmonary arterial hypertension, and the initial report was published in 2019. Their initial AI analysis algorithm has been used to provide a lower-cost screening at a significant population level, facilitate earlier diagnosis, and improve diagnostic rates and patient outcomes.

There was no reliably effective vaccine or specific drug invented for COVID-19 until the end of September 2020. Specialists have proposed several vaccines and drugs for COVID-19 by utilizing AI-based approaches. For example, the Harvard T.H. Chan School of Public Health and the Human Vaccines Project declared that they are using AI models to accelerate vaccine development by utilizing state-of-the-art techniques in epidemiology, immune monitoring, and network biology to explain effective immunity in older populations[44,45].

Public health policy development

Nowadays, many medical and health-related institutions use AI to assist in the early detection of infectious disease outbreaks and sources of epidemics[46]. Moreover, AI could also forecast adverse drug reactions, which causes about 6.5% of hospital admissions in the UK[47]. This indicates that AI could use big data analytic methods to assist in public health policy development.

When AI applications are deployed mainly in high-income countries, their use in low-income regions remains relatively nascent. However, AI systems in such low-income countries could support healthcare management in several ways. First, medical expert systems can assist clinicians in disease diagnosis and treatment plan selection, as performed in developed countries. AI could act as a human clinician in
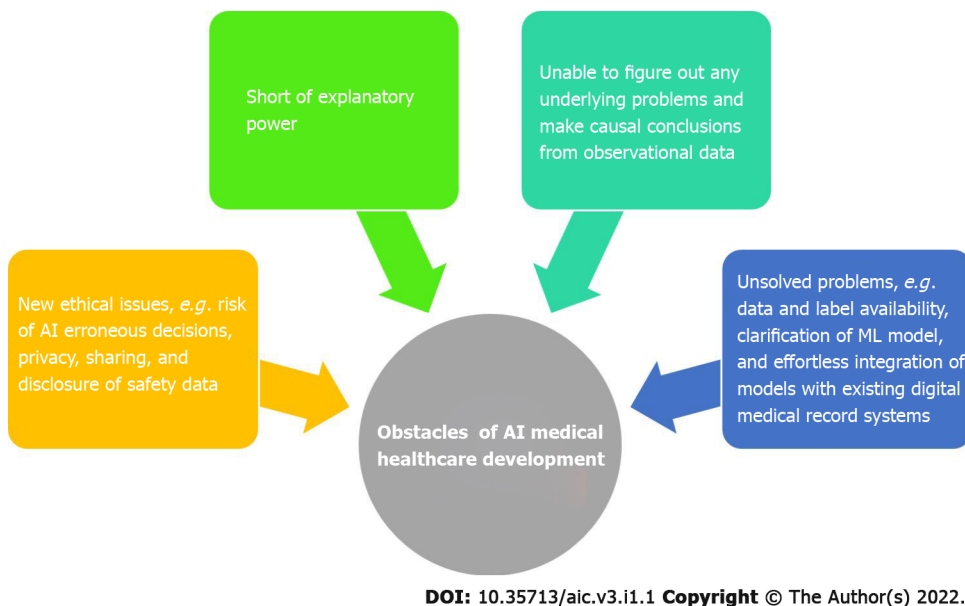
Figure 4 Current limitations of artificial intelligence medical healthcare development. AI: Artificial intelligence.

initial disease diagnosis in poor communities if one is not readily available. The sick could then be transferred to a suitable institution with the relevant medical resources. Furthermore, AI has already been used to forecast the disease model and delay its spread in epidemic situations worldwide, even in resource-poor regions[48].

LIMITATIONS OF AI MEDICAL HEALTHCARE DEVELOPMENT

Deep learning is short in explanatory power; deep neural networks cannot interpret how a diagnosis is made, and prejudice characteristics are difficult to identify[7]. This means that ML cannot determine underlying problems and is unable to make causal conclusions from observational data. Algorithms are efficient in outcome prediction, but predictors are not causes[49]. Furthermore, there are still problems that need to be solved, such as data and label availability, clarification of the ML model, and effortless integration of these models with existing digital medical record systems[50].

With the advent of AI development, new ethical issues have also been encountered after it intervened in medical practice, *e.g.*, risk of erroneous decisions by AI, responsibility of using AI in support decision-making, difficulties in confirmation of AI outputs, constitutive data biases in AI system training, sensitive data security crisis, assurance of public trust in AI medical interventions, and the possibility of AI being used for malicious goals[51]. Among these issues, privacy, sharing, and disclosure of safety data relating to AI applications must be strengthened and solved first (Figure 4).

ADVANTAGES OF CLINICIANS OVER AI IN PATIENT CARE

AI cannot replace the clinician's role in healthcare because it intrinsically lacks articulation and cannot generate insights[4]. However, AI could assuredly assist in making better clinical decisions and even provide more accurate judgment in specific healthcare fields[52]. ML has already alleviated much of the workload of radiologists and anatomical pathologists in many medical institutions due to its massive imaging database, accompanied by advanced innovation in computer vision. With rapid progress in AI performance, machine accuracy can overcome that of humans[53]. The expanding availability of healthcare databases and the fast progression of big data analytic methods have led to the success and popularity of AI applications in the healthcare field. In addition, powerful AI techniques can discover new clinical information hidden in the extensive database, further assisting clinical decision-making[54-56]. However, there are no universally applicable healthcare rules. AI must be complemented with clinician confirmation in many instances. Furthermore, the clinician-patient relationship is guided by associative thinking and could affect real-life treatment decisions. The impact of psychosocial and emotional factors on disease prognosis falls outside the AI scope, which should always be considered. Thus, most AI experts believe that a blend of human experience and digital augmentation should be the natural settling point for AI in healthcare (Table 1).

Table 1 Collaboration of human and artificial intelligence characteristics aiming to provide an ideal healthcare delivery

Human factors	AI factors
Clinicians could regard their patient as a fellow mortal, vulnerable being and gain detailed knowledge of the patient's disease related to their lives	AI continually coordinates new knowledge and perfects itself more rapidly than humans do
Clinicians know about social relationships and norms and could establish a genuinely intimate and empathetic connection with their patients	Automation of routine work could save time, such as documentation, administrative reporting, or even triaging images
The clinician-patient relationship could be guided by human associative thinking and affect real-life treatment strategies	AI could provide reliable diagnosis and treatment strategies, issue reminders for medication, provide precise analytics for pathology and images, and predict overall health according to the current medical database and patient information
The impact of psychosocial and emotional factors on disease prognosis and patient compliance could benefit from a good and close clinician-patient relationships	AI could provide simple mental health assistance *via* chatbot, monitor patient health, and predict disease progression

AI: Artificial intelligence.

CONCLUSION

Clinical medicine always requires professional staff to manage enormous amounts of data, from patient physiologic information to laboratory and imaging results. The capability of this complex management has separated excellent clinicians from others. AI has been regarded as an essential tool for clinicians in their daily practice. The increased application of AI technologies does not lower the value of face-to-face interaction with patients. On the contrary, because of AI, it is expected that clinicians would move toward the tasks that uniquely need social skills such as empathy, persuasion, and big-picture integration. Integrating the human clinician's 'hardware' with the AI's 'software' could provide an ideal healthcare delivery that exceeds what either could do alone. Perhaps the experts who refuse to apply AI technology in their clinical practice would be regarded as non-professional in the next decade.

FOOTNOTES

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