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Artificial Intelligence Applications in Cancer Diagnosis

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Abstract: Artificial intelligence (AI) is the use of mathematical algorithms to simulate human cognitive skills and to handle challenging healthcare concerns such as cancer. The exponential progress of AI in the recent decade demonstrates its promise as a platform for optimum decisionmaking by superintelligence, since the human mind is constrained to processing large amounts of data in a short period of time. Cancer is a complex disease with hundreds of genetic and epigenetic variants. AI-based techniques show significant potential for identifying these genetic alterations and abnormal protein interactions at an early stage. Modern biomedical research is also focused on bringing AI technologies to clinics in a safe and ethical manner. AI-based help to pathologists and clinicians might be a huge step forward in disease risk, diagnosis, prognosis, and therapy prediction. AI and Machine Learning (ML) clinical applications in cancer diagnosis and therapy are the future of medical guidance toward speedier mapping of a new treatment for each person. Researchers may cooperate in realtime and exchange information digitally by employing an AI base system method, which has the potential to treat millions. We concentrated on presenting gamechanging technologies of the future in clinics by linking biology with Artificial Intelligence and explaining how AIbased aid helps oncologists for accurate therapy in this evaluation.

Keywords: Artificial Intelligence, Machine Learning, Cancer, Medicine, Drugs, Discovery.

INTRODUCTION

Artificial intelligence (AI) and machine learning (ML) are progressively gaining traction in daily life and are expected to play a prominent role in digital health care for illness detection and treatment in the near future. AI and machine learning developments have paved the way for autonomous illness diagnostic tools by exploiting large datasets to tackle the future difficulties of human disease identification at an early stage, particularly in cancer. ML is a subset of AI in which neural network-based algorithms are built to enable the machine to learn and solve problems in the same way that the human brain does [1, 2]. Deep Learning (DL) is a subset of ML that mimics the human brain's capacity to process data in order to recognise pictures, objects, process languages, enhance drug development, improve precision medications, better diagnostics, and aid people in making choices. It can also function and provide an output without the need for human intervention [3]. DL can process data, including medical pictures, using an artificial neural network (ANN), which is comprised of input, output, and multiple hidden multi-layer networks to boost machine learning processing skills (Fig. 1) [4, 5].

AI is advancing at a breakneck pace. Clinical oncology research is increasingly focusing on decoding the molecular genesis of cancer by studying the complicated biological architecture of cancer cell proliferation. It also aimed to analyse millions of relevant cases in big data and computational biology in order to address the present global situation of increasing cancer mortality [6]. Furthermore, the application of AI in clinical decision-making is thought to boost the likelihood of early illness prediction and diagnosis using NGS sequencing and high-resolution imaging methods. It would also lead to the development of new biomarkers for cancer detection, the development of innovative tailored medications, and the delivery of prospective treatment options by creating large datasets and using specialist bioinformatic tools.

General AI is divided into three categories: (i) general AI, (ii) super AI, and (iii) narrow AI. Narrow AI can train a computer to figure out the most complex biological processes that humans are incapable of doing. With the advancement of AI technology, efforts have been made to create computers that can perceive biological changes similar to human intelligence by obtaining real-time and comparing data from the population pool for exact clinical interpretation [7]. Narrow AI is a kind of task-oriented programmed learning that is not influenced by emotions, as they are in humans. Limited AI: Apple's Siri, Amazon's Alexa, Microsoft's Cortana, and other language processing tools are typical instances of limited AI. The majority of these programmes handle human input (language or any supplied data), feed it into search engines, and return results to us. These computational Artificial Narrow Intelligence (ANI) techniques operate within a narrow range. Similarly, when we ask Siri, "What is the weather outside?" we get a correct answer since it is within Siri's specified artificial intelligence and such technologies are supposed to work in a certain manner. Furthermore, the most sophisticated self-driving automobiles are thought to function in the limited intelligence category (they are made up of many NAI systems) [8–11].

Nvidia, a renowned international technology corporation located in the United States, has declared its aim to construct an AI supercomputer for medical research and medicine delivery [12–14]. For the DL base algorithm to detect cancer at an early stage, effective translation of an AI-based application needs domain-specific knowledge in academics, i.e., "cancer cell biology." Of course, oncologists must study AI technology in order to avoid common mistakes and ensure its safe and ethical application.

In this study, we focused on the ground-breaking convergence of biology and AI techniques to address future health-care concerns. The future of medicine involves virtual and physical support from technology through information management and robotic technologies. In medicine, an AI-based strategy is being developed to solve difficult biological problems, uncover complex protein–protein interactions, and find therapeutic targets. The paper also discusses several trained deep-learning design models for discovering novel medications and assisting in robotic surgery. AI also has the outstanding potential to increase diagnosis accuracy by detecting aberrant alterations at the cellular level in medical imaging technologies. It also discusses "AI-based precision oncology techniques" for precisely targeting individual cells, as well as its role in overcoming NGS constraints using AI-assisted toolsets. This study also discusses AI-based applications in digital pathology and ethical considerations in depth to keep readers up-to-speed on the future of medical technology.

AI IN MEDICINE

Clinical AI enables computers and robots to replicate human intelligent behaviour, build medicine formulations, aid in clinical diagnostics and robotic surgery, create medical statistical databases, and analyse the cellular architecture of human illnesses such as cancer. AI has both a virtual and real influence on medicine. The virtual component is based on DL information management technologies and can understand and manipulate information datasets for electronic health records as well as aid the clinician in precision decision making. To increase learning via experience, DL employs a mathematical method. The physical system of AI, on the other hand, may aid in robotic-assisted surgery and nano-robotic applications for targeted medication administration [15].

The application of logistic data mining and DL in clinical diagnostics allows the ML to reason and assists clinicians in making treatment choices. When AI-based IBM Big Blue ultimately beat World Chess Champion "Gary Kasparov" on May 11, 1997, it gained widespread recognition in the scientific world. Today, AI is capable of resolving complex problems, including complex biological challenges, and has been employed in robotic surgery for heart valve replacement, gynaecological illnesses, prostatectomies, and is expected to play a major role in the battle against cancer in the future [16–18].

There are three types of machine learning algorithms: (1) supervised learning (which predicts algorithms based on past knowledge); (2) unsupervised learning (which identifies hidden patterns without labelled answers); and (3) reinforcement learning (the use of a sequence of either rewards or penalties for the action it performs, like a video game model). The significance of AI in medicine has grown as a result of discoveries in molecular medicine and genetics made possible by computational biology algorithms and information management. An unsupervised protein–protein interaction algorithm has been claimed to have reached a critical milestone in the development of therapeutic targets [19]. An evolutionary embedding algorithm was used to identify novel DNA variations as early-stage risk factors for several human illnesses, including cancer [20–22]. The employment of advanced medical technologies, including robots, to monitor patients' critical conditions in real-time "care bots," particularly for elderly patients, and to aid surgeons in surgery is a physical branch of AI in medicine [23].

AI in medicine has the potential to improve health care by making it safer, more accurate, and quicker. Huge datasets have been created and are being updated on a daily basis to assess the clinical effect of AI in medical radiography. In Scotland, the AI-based clinical assessment service "National Health Service" (NHS 24) is in the clinical trial phase to help the population with minor health concerns at home by telephonic call [24]. Similarly, another online healthcare company, "Babylon Health," provides complementary digital services to enhance clinical results using semantic web technology. The semantic web is intended to make internet data machine-readable. The use of AI-based medical services and the development of clinical LDG (Linked Data Graph) to connect diverse bioinformatics-based biomedical data banks in a comprehensible manner for the general public [25]. In medicine, logic-based reasoning approaches are thought to have substantial effects.

With computational aid, a massive quantity of radiology, genetics, and microbiology-related data may be systematically gathered and handled for tailored therapy. The development of AI-based supervised and unsupervised tools is still in its early stages, and additional advancements are required to eliminate the projected mistakes [26]. The support vector machine method and causal probabilistic network tools have been shown to have high accuracy in predicting infection-related carcinogenesis and have been suggested for appropriate therapy options [27].

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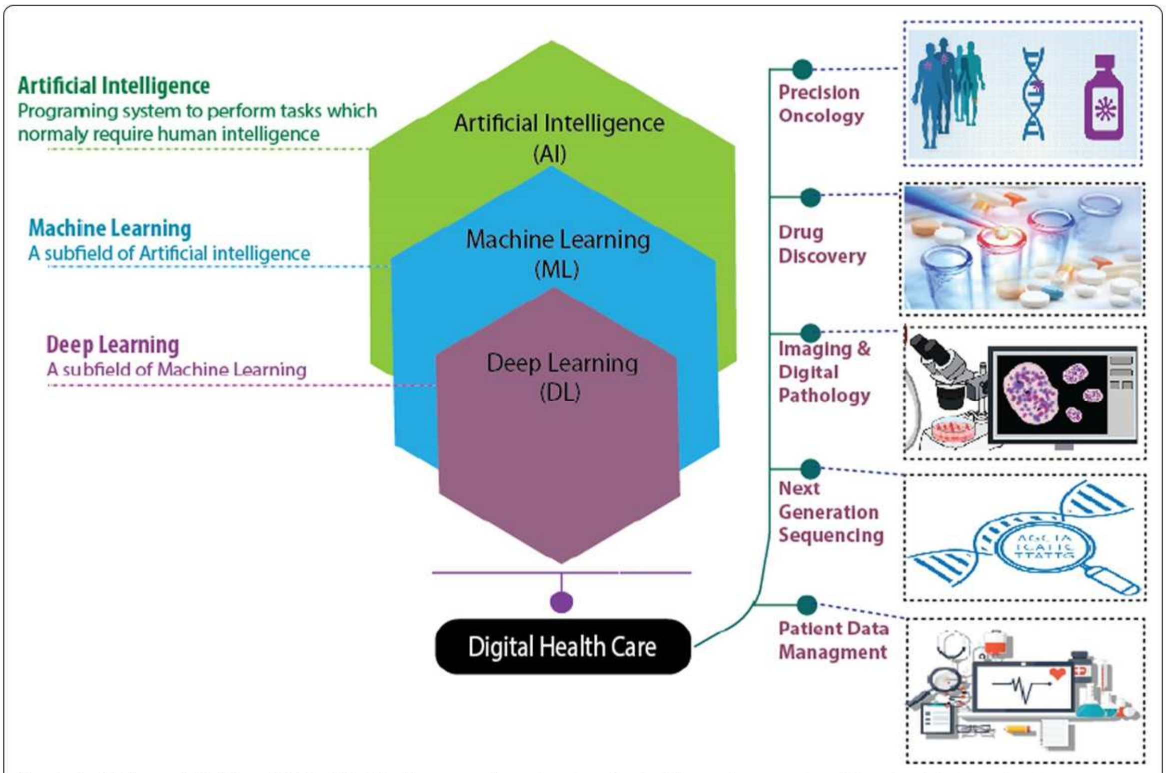

Fig. 1 Applications of AI, ML, and DL in digital health care and oncology to solve healthcare issues and predict optimal treatment outcome

Clinical researchers are now focusing on large-scale ML algorithms, which are thought to give computers the ability to learn from massive pharmaceutical data sets on an industrial scale, allowing them to discover new drugs at a lower cost and in a shorter period of time by utilising supercomputers and machine learning tools, as previously used in self-driving cars. The Exascale Compound Activity Prediction Engine (ExCAPE) project is one of the big data analysis chemogenomic initiatives for the chemical compounds to target biological proteins in in silico models funded by Horizon 2020, a European financing programme. The goal is to assemble comprehensive chemogenomics information from legitimate databases (ChEMBL and PubChem) in order to predict protein interactions and gene expression for large-scale pharmaceutical businesses [28]. ExCAPE is a scalable ML model for complex information management and its industrial applications, particularly in the pharmaceutical sector, to predict chemical biological activity and protein interaction. Various intricate biological restrictions must still be addressed at a scaled level through an algorithm, and it is predicted that this study will be expanded further by speeding up ML-based supercomputers for quick drug discovery. Microfluidic and AI-assisted drug design are two recent advancements in medicine for chemical synthesis [29]. It has been well shown that when applied to pharmaceutical company datasets, trained DL-derived ML models outperform all comparative practise methodologies [30].

AI IN MEDICAL IMAGING OF CANCER

Because of its DL and problem-solving abilities, AI has captured the attention of the scientific community. Alan Turing initially proposed the concept of AI in his work "Computing Machinery and Intelligence" [31] in the nineteenth century. We are now at the beginning of the AI-based technological age, although just ten years ago, the number of publications on AI-related medical imaging was relatively restricted. This figure reached 800 in 2016–2017 and is anticipated to skyrocket in the coming years [32]. Medical imaging technology, which is based on computational models and bioinformatics-based algorithms, provides a good progressive possibility for medical

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imaging technology (MIT). It can detect abnormal cellular development and biological changes in the body [33].AI-assisted MIT not only has a significant influence on radiology but also on medical resonance imaging and neuroradiology. AI offers a wide variety of dynamic applications, including picture interpretation and categorization, data subsequent layout, information storage, information mining, and many more. AI is expected to significantly aid radiologists in enhancing diagnostic specificity due to its broad reach in biomedical imaging technology [34].

Without radiology, the healthcare system would be incomplete, particularly in the case of cancer and other cancer-related consequences. Radiologists are expected to be more technologically savvy than any other medical practitioner. They are continually on the cutting edge of adopting digital medical imaging information [35]. At a glance, AI could detect aberrant data, demonstrating a high sensitivity rate when compared to other traditional technologies [36]. Of course, radiologists should play an important role in communicating with patients whose findings have been interpreted by AI. AI will never replace radiology at this moment, but the demand for radiologists is reducing with time due to AI's image interpretation efficiency. Experienced radiologists who are technologically inclined are in high demand to create customised algorithms for high-throughput data processing with high precision and accuracy. After executing a broad variety of experimental investigations, AI-based algorithms can uncover specific patterns to offer information regarding anomalous results. Traditional computer-aided detection (CAD) systems can identify the presence or absence of picture characters, but AI-based systems extract all visible and nonvisible image characteristics to provide more exact findings [37, 38].

The algorithm-based smartphone application "Skinvision" (https://www.skinv.ision.com) is a mobile-based tool that can assist a user through the process of doing frequent self-checks for skin cancer using a phone and a snapshot of a skin spot. The algorithm, like a doctor, can determine the texture, colour, and form of the lesions. Users receive an immediate risk assessment for skin lesions in 30 seconds, and the algorithm has been shown to detect 95 percent of skin cancer at an early stage [39].However, physician intervention is still required since we cannot depend entirely on the algorithm.

Because of its great performance and AI-based cognitive abilities, DL is preferred over classical ML. It has not only improved the picture graphics but also decreased the cost and time of the procedure [40].

AI IN PRECISION ONCOLOGY

Precision oncology is the targeting and characterization of individual tumour cells. It is thought to be a crucial therapy method in the battle against cancer, with the goal of identifying particular molecular targets. Precision oncology is associated with tailored cancer genomic data, but it may also recruit proteomics data by obtaining clinical signatures from electronic records in multiple computational databases [41, 42]. Recent gains in clinical oncology have been made using AI-based innovative molecular techniques. Next-generation sequencing (NGS) is an excellent platform for producing high-throughput data sets. It also necessitates the participation of oncology experts with ML backgrounds in order to design algorithms for early-stage cancer detection through the identification of novel biomarkers and target sites, precise diagnosis through NGS sequencing, selective target site identification, and high-resolution medical imaging technology [6, 43]. Precision oncology medications are treatments that are intended to target individual cancer cells based on their genetic diversity. The NGS data may assist the algorithm in recommending successful medication by taking into account personalised genetic characteristics (Fig. 2).As a result of systematic data processing from pharmaceutical and clinical huge datasets, AI is considered among the top future therapies for accurate cancer diagnosis, prognosis, and treatment.

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Future digital healthcare and clinical practises are expected to shift toward the use of algorithm-based AI help for radiological image interpretation, E-health records, and data mining to give more accurate cancer treatment solutions.

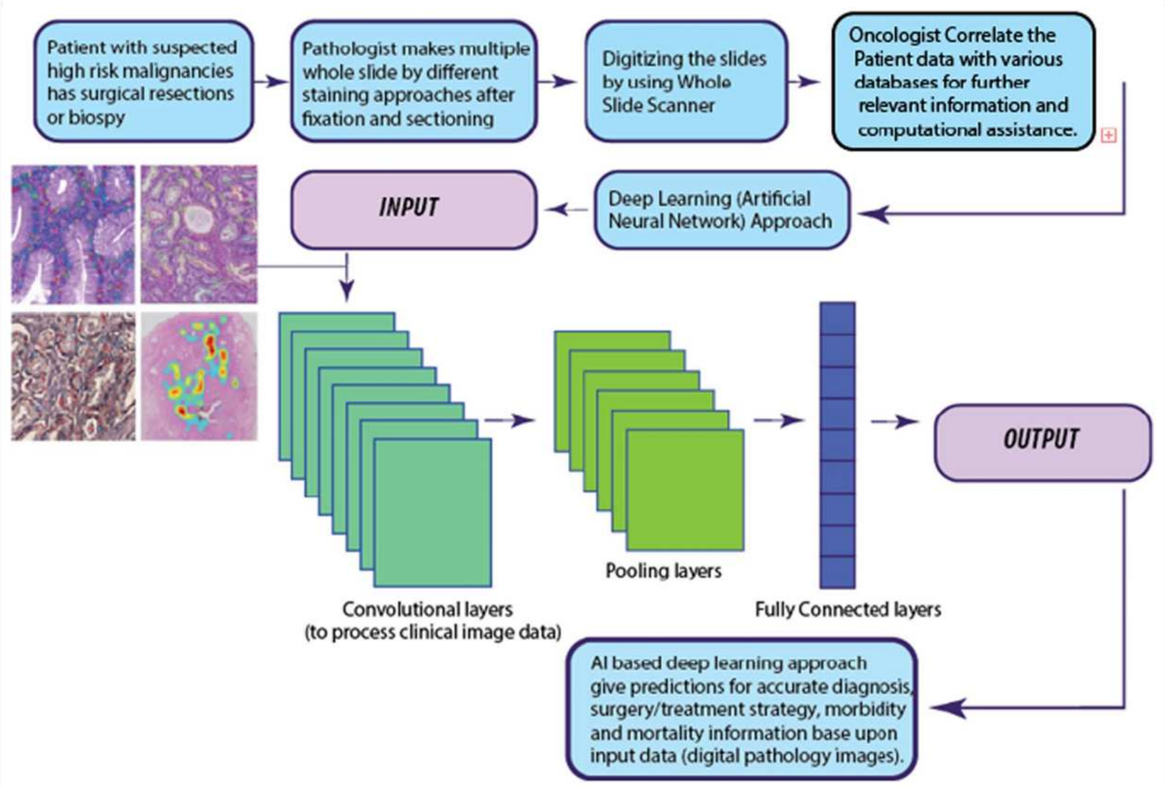

Fig. 2 Workflow for Artificial Intelligence approach for digital pathology

NGS technology and genomic profiling have proven to be the most important advancements in precision oncology during the previous decade. Sanger proposed the first generation sequencing technique in the 1980s, which included fragmenting the targeted DNA area and cloning using a plasmid vector. In this methodology, tagged fluorescent dNTPs were employed for sequencing using the chain termination method, which takes time and yields little data output.

AI IN DRUG DISCOVERY

With the technical influence of biomedical engineering and bioinformatics, NGS technology introduced a 2nd generation sequencing technique in 2005, processing large-scale sequencing data in a short amount of time and at a low cost. Whole genome, whole exome, whole transcriptome, RNA, and short-gun methylation sequencing are exciting novel NGS applications that have been extensively employed in cancer research and diagnostics to identify mutant genes and aberrant molecular pathways for new targeted drug development [44, 45]. Large-scale molecular profiling of RNA has been increasingly recognised for use in a variety of cancer treatments and has proven to be the standard of care for cancer patients. Precision oncology has made extensive use of RNA expression signatures [46]. DNA or RNA library preparation is a prerequisite for 2nd generation sequencing protocols such as Ion Torrent, Ion Torrent Genexus, Illumina MiSeq, and Illumina HiSeq 2000. This approach to creating a DNA/RNA library is a difficult procedure that may potentially result in mistakes [47].

To address the constraints of the second generation sequencing technology, the third generation NGS method was recently established, simplifying genetic sequencing and decoding. The Pac

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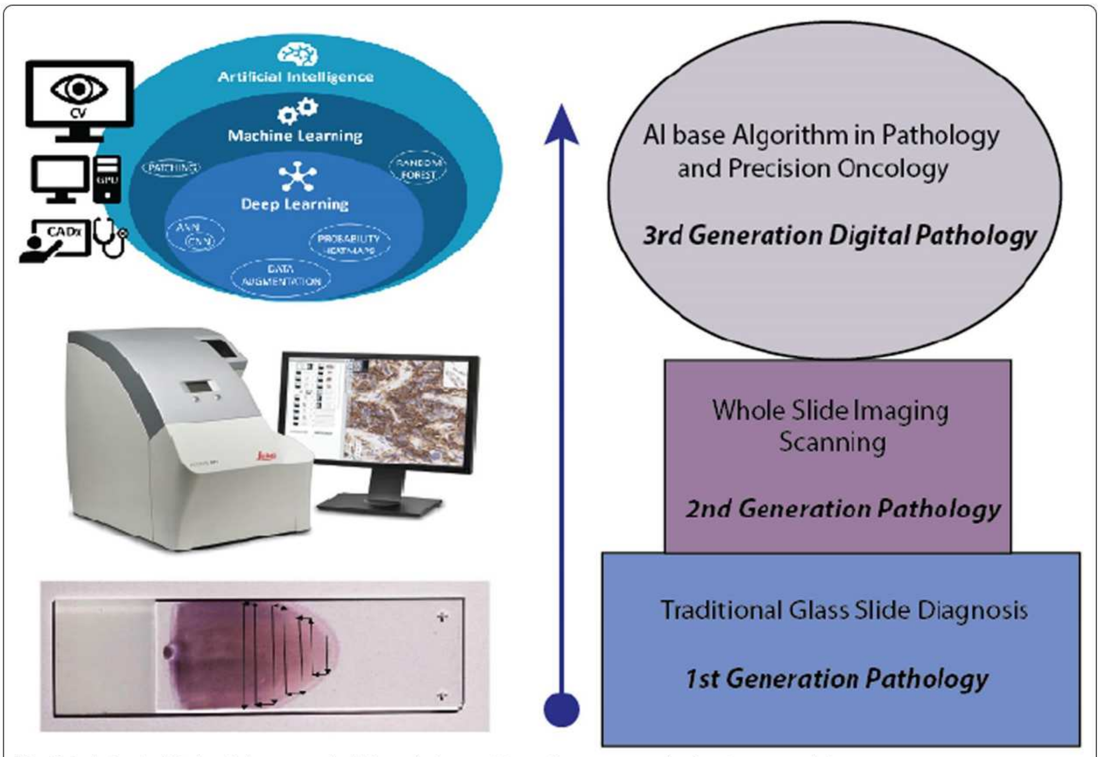

Fig. 3 Evolution in digital pathology towards high-resolution graphics and easy storage plus data interpret solutions

Bio-RS and Oxford NanoPore sequencing platforms can sequence lengthy strands of DNA or RNA on portable devices with little effort and cost.

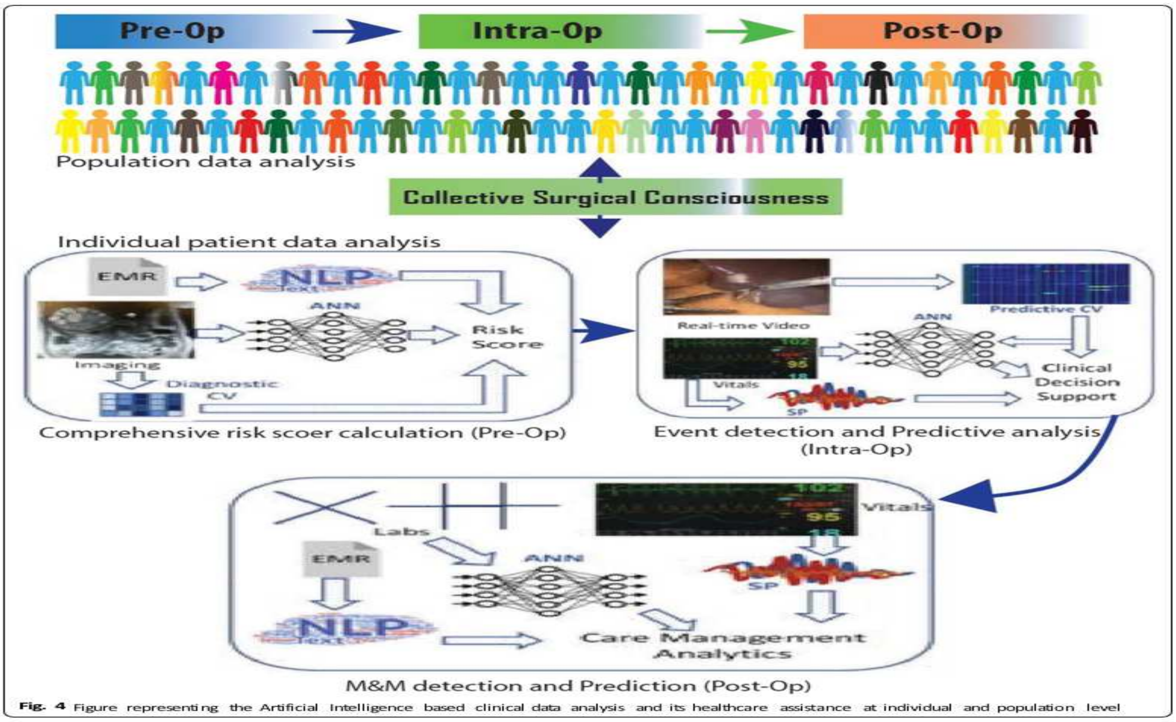

Fig. 4 Figure representing the Artificial Intelligence based clinical data analysis and its healthcare assistance at individual and population level

Without the need to build a genetic library [47], The AI-assisted toolsets on the NGS platform can analyse complex genomic data patterns. Computational biology methods can decipher genetic

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information and relate it to the molecular pathways responsible for the emergence of clinical illnesses such as cancer, allowing precision oncology medications to be implemented [48].

Such massive NGS-based datasets may be efficiently handled by AI-assisted technology to determine the pattern of genotypic variations by taking regional genetic pool data and any other important biological elements into account. These biological characteristics might be specified by a machine learning system that conducts supervised or unsupervised analysis, identifying any genetic variation and linking it to early cancer prediction and medication development [49].

AI IN MODULAR CASCADING SIGNALING IN CANCER

Digital pathology will become more important with AI and machine learning-based computational tools. Deep neural network (ANN) systems will be used for precise tumour imaging with high resolution, as well as the creation of new biomarkers [50]. Digitalizing medical pathology has enormous promise for enhanced cancer diagnosis, and this digitalization is based on slide scanners converting histopathological slides into high-resolution pictures. Digital whole slide images (WSI) are currently exposed to ML systems for DL analytical processing, which may ensure the comprehension of biological problems in cellular architects, perhaps leading to the development of a new generation of biomarkers for successful cancer treatment (Fig. 3) [51].

Biomarkers are biological indicators that may be used to identify human body tissues and cells. Today, drug development is plagued by a slew of issues, including significant failure rates in lieu of sophisticated clinical and pre-clinical studies. To increase the success rate, there is an urgent need to uncover a new generation of biomarkers using computational methods for meaningful clinical practise and drug discovery.

The first large-scale diagnostic investigation in digital pathology was conducted, including around 2000 patients and more than 16,000 readings (data files in various clinical formats) of various tumour kinds. This research paved the way for digital diagnostics by using a digitised WSI system. Biomedical engineers and data scientists are spearheading a number of research initiatives for innovative AI-based image analysis in cancer. Currently, AI-based analysis of patient radiography, morphological patterns, and histology data is thought to increase diagnosis accuracy via the use of new biomarkers for precision oncology [52].

Artificial intelligence and ANN learning processes operate in layers. Each layer is a container for neurons, and data processing necessitates grouping between various layers (neurons). Dense (completely connected) layers, convolutional layers, pooling layers, recurrent layers, normalising layers, and many more are all specialised to conduct certain functions, just like human differentiated cells. Convolutional layers are designed to handle imaging data such as digital pathology pictures. The process for an AI method in digital pathology is shown in Figure 3.

In 2010, a group of researchers published a supervised ML model for identifying numerous distinct cellular properties and patterns in breast cancer pictures based on previously established diagnostic data by expert cancer pathologists [53].

AI IN CANCER SURGERY

Without a doubt, artificial intelligence has taken the globe by storm. It has been reverberating throughout the world since the 1960s and continues to be a game changer in every sector. Medicine is no exception; in fact, oncology is working hard to comprehend the complicated algorithms at the root of cancer. Cancer claimed the lives of an estimated 9.6 million people in 2018 [54].Up to 200 different forms of cancer have been identified, and it is predicted that cancer will be the main cause of death by 2030 [54].

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Many high-throughput methods have been utilised to detect gene expression. Microarray technology is often used to detect genetic expression, but it has many disadvantages, including the fact that it is costly, requires professional handling, and analyses genetic information from a huge pool of data sets. As a result, oncologists recognised the need to develop a cancer molecular signature to identify the expression of abnormal genes. They tracked the patient's treatment response and subsequently developed strategies for precision disease management. ML is currently being used effectively in CAD. Medical specialists all over the world are exchanging diagnostic and treatment data, and with AI technologies, such data might be automatically saved (cloud scaling). This resulted in the creation of the Tumor Atlas [55].

To beat the human intellect, AI primarily employs two approaches: neural networks and fuzzy logic. A neural network is incredibly difficult to read (it is a black box), but fuzzy logic is easily interpretable. Medical professionals, on the other hand, use both to detect breast cancer [56].Several kinds of cancer, including pancreatic and stomach cancers, are only discovered after they have progressed to the late stages. Similarly, lung cancer screening is a time-consuming and difficult operation. Medical professionals utilised a low dosage CT scan approach for screening, which was inadequate to monitor this cancer type when compared to blood profiling, in which AI-based technologies analysed the plasma profiles of ctDNA and miRNA [57].

Cancer therapy is set to be transformed by AI, the most powerful yet intelligent weapon in the battle against cancer. Nonetheless, the dearth of computational methods and information technology understanding among doctors and physicians prevents AI application in underdeveloped nations.

ML BASED ROBOTIC THERAPY

An exciting area of study is novel AI-based applications and current developments in surgery. For decades, clinical machine interaction has aided oncologists. AI assistance has been shown to significantly reduce the incidence of breast conserving surgery (mastectomy) by 30.6 percent, whereas in previous practices, high-risk patient tissue samples were only proven benign after surgery [58].In today's clinical practice, ML models that reliably forecast high-risk cancer lesions using image-guided needle biopsies and pathology updates are a critical necessity in today's clinical practise because they help reduce unnecessary surgical excisions. Various research groups have created random forest ML models to predict cancer survival and long-term cognitive prognosis. A random forest ML model was used to examine 335 high-risk cancer patients in a clinical investigation, and it was discovered that it might avert approximately one-third of unnecessary procedures [59]. Because breast cancer is the most common cancer type in women globally, multiple ML-supportive studies have lately been conducted. In these investigations, neural network, extreme boost, decision tree, and support vector machine models were employed to identify and obtain visual cancer signatures in order to establish new prognostic indicators for reliable survival analysis [60–62].

For surgical operations in the operating theatre, the Collective Surgical Consciousness (CSC) for individual and population data analysis has recently been acknowledged. The computational approach has been employed in a few clinical contexts where an artificial neural network (ANN) based on digital image processing computed a pre-operational complete risk assessment. Similarly, ML assistance is available during surgery; indeed, through surveillance cameras and real-time video images, ANN can provide supportive clinical decisions and predictions based on whole population data analysis from the specific genetic pool data (patient age, gender, and other body biological parameters). Fig. 4. Furthermore, the use of AI and ML may help oncologists assess and

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forecast morbidity and mortality following surgery. Similar to Siri, such AI can recommend clinical care and personal care management plans based on real-time analysis [63, 64].

CONCLUSION

Machine learning has a significant influence on healthcare operations. It may have an impact on therapy and diagnosis, raising major ethical concerns. The applications of machine learning in healthcare vary from completely autonomous AI for cancer detection to nonautonomous mortality forecasts to help healthcare budget allocation [65]. AI and machine learning (ML) therapeutic breakthroughs span from virtual psychotherapists to social robots in dementia and autism. Therapeutic chatbots, avatars, and social assistive gadgets are being translated into clinical applications, and their ethical problems are mostly focused on long-term uses of AI and therapeutic robots, which may lead to total patient reliance (socially not acceptable). Furthermore, the incorporation of AI gadgets into daily life and medical treatment is affecting moral judgement and societal expectations since there is a significant gap between human and machine communication [66]. Transparency is the most challenging challenge with today's AI. Many AI and ML systems, especially deep image analysis techniques, are incomprehensible and difficult to understand. Even scholars and doctors who are acquainted with the procedure are unable to describe it [3]. Others have claimed that using AI and ML in therapy or diagnosis indefinitely might be detrimental since distributional changes can occur, implying that goal data will not match current patient data and would lead to incorrect conclusions. The relationship between data pieces is expected to change as the population (gene pool), technology, and methods of care evolve [67]. Another area where AI may be used is in mental health practise centres, where it can improve patient autonomy. These AI and ML technologies need patient instruction to guarantee that the patient does not misinterpret the intelligent system for a human-driven application. Furthermore, permission obtained outside of a medical context raises perplexing issues [68].AI is prone to erroneous judgement and risk-taking.

There is little question that surgery, chemotherapy, and radiation will continue to be the standard cancer treatment for many years to come, but the scientific community is increasingly interested in further developing the present clinical cancer methods. Computational input and support will be a concrete reality in the future clinical context, resulting in a substantial technology revolution to forecast and diagnose human health-related disorders in real-time.

AI avoids emotional issues, cultural and moral views, and exhaustion [69]. Optimal decision-making intelligence and continual improvement through artificial neural networks and deep learning would be ideal instruments to aid medical doctors in the identification and exploration of carcinogenesis in a timely manner. The natural human mind has a limited capability for processing massive amounts of data and accessible information [70].

Although they are popular among the technology-oriented scientific community, AI-based DL techniques have several limitations at the micro and macro levels for the healthcare sector. These limitations include an unregulated training set algorithm, unsupervised learning implementations, patient data confidentiality, data set size, and classification based on more than 100 different types of cancer, all of which necessitate significant attention to human computer interface (HCI) and AI use [69]. Reproducibility of clinical testing is one of the most significant barriers in molecular drug development since it takes several years after clinical trials to introduce a successful formulation to the market. Reproducible computation drug design has been identified as a viable approach for future drug development because of its improving specificity and cheap cost [71].

The analysis of big data and ML technologies can handle the evaluation of a huge range of sophisticated and varied health care data to reduce limitations and false-positive data [72]. Finally, AI in clinics does not imply the abolition of radiologists and other medical experts. However, AI is

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not completely self-sufficient and cannot replace human intervention.In the medical industry, AI is a unique and potentially useful instrument for achieving a particular treatment performance and identifying an accurate diagnosis at the highest level feasible.

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