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Exploring the Pivotal Association of AI in Cancer Stem Cells Detection and Treatment

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Abstract: Cancer stem cells (CSCs), or tumor-initiating cells (TICs), are cancerous cell subpopulations that remain while tumor cells propagate as a unique subset and exhibit multiple applications in several diseases. They are responsible for cancer cell initiation, development, metastasis, proliferation, and recurrence due to their self-renewal and differentiation abilities in many kinds of cells. Artificial intelligence (AI) has gained significant attention because of its vast applications in various fields including agriculture, healthcare, transportation, and robotics, particularly in detecting human diseases such as cancer. The division and metastasis of cancerous cells are not easy to identify at early stages due to their uncontrolled situations. It has provided some real-time pictures of cancer progression and relapse. The purpose of this review paper is to explore new investigations into the role of AI in cancer stem cell progression and metastasis and in regenerative medicines. It describes the association of machine learning and AI with CSCs along with its numerous applications from cancer diagnosis to therapy. This review has also provided key challenges and future directions of AI in cancer stem cell research diagnosis and therapeutic approach.

Keywords: Artificial intelligence; Cancer; Cancer stem cells; Health

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1. Introduction

Artificial intelligence (AI) powerful statistical abilities have an opportunity to completely transform cancer research, diagnosis, and therapy. Strong computing skills are therefore required to merge information with complex results from studies, a potential made possible by big malignant study information that has never been seen before [1]. To address the high complexity faced by healthcare facilities, including that which is presented by biological system anomalies like cancer, AI uses algorithmic mathematical principles that replicate the functioning of the human brain. Modern medical diagnostics and treatment will likely be dominated by AI and machine learning (ML), which are already expected to have an important effect on everyday life [2]. Recent advances in AI and ML have made it possible for tools for diagnosing autonomic neuropathy disease to use massive amounts of data to address the difficulty of human disease identification at an incredibly early stage, especially in cancer [3]. Cancer is among the two leading reasons for mortality globally and is a major public health concern. Uncontrolled cell division that results in aberrant cell creation and quick body expansion is a hallmark of cancer. Complex in nature, cancer arises from healthy cells primarily due to aberrant cell division and an elevated burden of mutations [4]. It is a complex condition that makes early diagnosis challenging. For this reason, the scientific community and researchers are primarily concerned with multifactorial disorders and cancer therapy. Cancer is one of the toughest conditions, and even with international initiatives, the prevalence of cancer patients is rising [5]. Initial cancer screening and diagnosis are less precise, and the majority of patients do not receive a diagnosis using the methods and procedures that are currently in use. Current breakthroughs in combination chemistry, genomics, and proteomics have made a multitude of databases containing living and chemical information available. These advancements have the potential to greatly advance our knowledge of the molecular biology of cancer [6]. A deeper comprehension of cancer biology could have a big impact on the way we diagnose and treat patients with cancer in hospitals.

Similar to other kinds of cells, tumors also sense sensory signals from their environment, which affect DNA transcription, cell conduct, and efficiency. Cancer cells are only one component of the procedure of cancer development [7]. The extracellular matrix (ECM), non-cellular constituents, invasive cell elements, and signaling chemicals form a complex structure that is known as the tumor microenvironment (TME) [8]. Software developers and healthcare scientists can now collaborate directly to use multi-factor assessment to enhance prediction because of scientific improvements. It has been reported that such analyses yield much better results than actual estimations. Scientists are currently focusing on creating models that use AI algorithms to recognize and anticipate cancer as part of the AI application. These methods are now being applied to increase the precision of their existence, return, and cancer prognosis [9].

The TME's many genomic and noncellular elements exchange information back and forth. Tumor development may be influenced by biochemical signals as well as topography, rigidity, shear stresses, interstitial flow, and fluid pressures. In a tumor wound, an abnormal circulation that produces a differential of nutrients, oxygen, and metabolic waste products leads to the development of a necrotic core [10]. The cells in the core region become dormant and change making their eradication difficult. They also produce hypoxia-inducible proteins and other cytokines that may affect the bodily functions of surrounding cells [11]. Furthermore, the way malignant cells spread is regulated by relationships between cells and the ECM in the manner of extracellular matrix transformation, perivascular tissues, fibroblast application, and immune systems. The TME is essential to the tumor's evolution because it actively communicates with the adjacent environment in both directions, encouraging and stimulating the development of the tumor and its spread [12]. Moreover, a substantial body of research has demonstrated the TME's protective function in halting tumor growth and spread in the initial levels of tumor formation, and how "re-programming" the TME in these stages afterward could greatly advance the growth of cancer treatments [13].

Hypoxia is necessary for cancer cells to thrive, so to support cancerous cell life, hypoxia-inducible factor-1 (HIF-1) binds to react to components of hypoxia, activating numerous genes in the process. HIF-1-specific genes majorly regulate tumor metastasis, angiogenesis, pH, attachment, and metabolic processes. The TME, composed of stromal cells, secreted chemicals, and ECM proteins, is a complex mechanism including tumor cells [14]. A malignant composed of changed, constant cell division is not the sole formation caused by cancerous cells. The growth, advancement, and aggressiveness of tumors depend critically on their association with these microenvironmental components [15].

The metabolic regulation of metabolic processes constitutes one of the features of cancer that contributes to its growth. Oncogenic processes lead to abnormal metabolic processes and confer unfair benefits on tumor cells that facilitate increased proliferation and survival in unfavorable surroundings [16]. Other ways that a repaired physiology effectively encourages the growth of tumors include the synthesis of oncometabolites connection to signals, and metabolite-dependent regulatory control. The alterations in the metabolic cycle of tumor cells have an impact on nearby TME cells and aid in regulating significant events involved in the growth of malignancy, such as angiogenesis, inflammation, and cancer resistance [17]. Therefore, analyzing the biochemical interactions between cancer and healthy cells in the TME could identify vulnerabilities associated with cancer and provide fresh possibilities for cancer detection and therapy [18].

The clinical oncology-based investigation is primarily concerned with determining how tumor cells proliferate to shed light on the disease's biological origin. Additionally, it sought to address the growing global cancer mortality toll by using machine learning to handle massive amounts of data from millions of appropriate situations [19]. Furthermore, it is anticipated that applying AI to medical decision-making could facilitate the use of high-resolution imaging and NGS to forecast and detect disorders early. AI can be used to synthesize fresh biomarkers for tumor diagnosis. This requires the creation of novel, individualized medications as well as the provision of prospective therapy regimens through the creation of sizable databases and the application of bioinformatics techniques [20]. The goal of AI working is to create an environment that is appropriately educated to effectively advise on whether or not an individual will need immunotherapy. AI can determine which individuals require additional evaluations, such as whole genome spectroscopy, and which immunotherapy medication will have the greatest effect on a patient's rehabilitation [21].

The increased use of AI in healthcare is combined with real-world case research that has been published up to this point to fully address the gaps and restrictions in the diagnosis of different kinds of cancer. Also, a thorough explanation of the structure needed for AI to function is provided. The primary goal of the present review was to examine how biological and artificial intelligence might be used to tackle cancer-related health problems in future decades to keep scientists informed about how AI will be used in computerized forensics and detection and how it will impact cancer therapy over time.

2. AI and common therapeutic approaches

AI in cancer treatment concentrates heavily on the interaction between patients and medications. The control of chemotherapy medication intake, the estimation of chemotherapy drug dependence, and the improvement of chemotherapy programs are among the primary applied accomplishments of AI. AI has the power to streamline and expedite the procedure of optimizing combination chemotherapy [22]. Choudhary *et al.* have created a deep learning-based diagnostic method that can identify tumor cells with HR defects with 74% reliability and identify patients who could profit from PARP medicines. A machine learning algorithm created by Khan *et al.* can forecast if breast cancer would tolerate chemotherapy. The research managed to discern the connection between the adverse reactions of two chemotherapy medications, taxol and gemcitabine, by examining the connection between the patient's genes and the treatments [24]. Furthermore, research has demonstrated that the deep learning technique outperforms the Epstein-Barr Virus-DNA-based framework in terms of risk division and initial chemotherapy direction for nasopharyngeal cancer. This suggests that the deep learning approach's directing function could be a useful predictor of single-induction chemotherapy for developed nasopharyngeal cancer [25]. **Table 1** summarizes the key roles of artificial intelligence in cancer stem cell detection and therapy from previous studies.

Table 1. Artificial intelligence in cancer stem cell study

Application	Used AI strategies	Explanation	Advantages
Identification	ML image analysis	ML algorithms used to recognize CSCs using images	Better and more precise recognition of CSCs than manual analysis [65,66]
Treatment	ML for suitable drug discovery	AI models help to set and identify underlying drugs for CSCs	The significant discovery of novel therapeutic strategies to target CSCs and mitigate sources of cancers [67,68]
Treatment	Predictive modeling	Patient reactions to the used treatment strategy were assessed against CSCs	Increases precise therapeutic approaches and diminishes side effects targets [69,70]

The use of AI innovation has a greater emphasis during cancer radiation treatment. AI can be used by radiologists to autonomously plan radiotherapy schedules or map out regions of interest. Considering a precision of 79%, Chen *et al.* worked on automated nasopharyngeal cancer delineation using the three-dimensional convolutional neural network (3D CNN) corresponds to that of radiation professionals [26]. Using machine learning and radiomics—a technique for obtaining picture attributes from radiographic images developed a prediction model that assesses how well bladder cancer treatments will work. By using deep learning gadgets, one of the studies created computer programs that cut the time needed to schedule radiation treatment down to a brief period [27].

AI is mostly used in cancer immunotherapy applications to assess therapeutic efficacy and assist doctors in modifying the medication regimen. A study created a machine learning-based artificial intelligence system to precisely forecast the curative effects of programmed cell death protein 1 (PD-1) antagonists [28]. This system is useful for assessing the impact of immunotherapy in patients with PD-1 inhibitor-sensitive progressive solid malignancies. A machine learning technique derived from the human leukocyte antigen (HLA) mass spectrometry database was developed and has the potential to enhance the effectiveness of tumor immunotherapy by improving the detection of cancer neoantigens [29]. To prevent patients from receiving unnecessary treatments, an algorithm can efficiently recognize precancerous abnormalities from computerized pictures of women's cervixes that require therapy. A machine learning method can lessen the overtreatment of tumors thought to be breast cancerous. With the use of this technology, physicians can prevent needless surgery and establish informed choices regarding treatment by identifying high-risk breast lesions that have the potential to develop into cancer [30].

Deep learning technologies improve the intelligence of cancer therapeutic decisions. Artificial Intelligence can identify the best course of therapy for physicians based on its understanding of medical large amounts of information from cancer victims. A Clinical Decision Support System (CDSS) built on deep learning algorithms was formed [31]. It can produce alternative therapies for cancer by extracting and analyzing an enormous quantity of diagnostic information from health records. The study highlights how crucial AI innovation is to doctors' efforts to enhance patients' cancer therapy regimens. AI's capacity for deep learning and innovative solving issues has brought its capabilities to the attention of scientists and researchers [32].

3. AI in anticancer drug formation

Models that anticipate how tumor cell lines, as well as individuals, will react to novel medications or treatment mixtures can be created by training machine learning techniques on high-throughput testing information. By employing machine learning to design and construct reverse synthesis processes for chemicals, researchers are speeding up the process of finding new drugs. A great deal of information is generated throughout the entire procedure of developing a new medication [33]. Our ability to analyze chemical information and produce outcomes that will aid in creating drugs is greatly enhanced by machine learning. We may analyze information gathered over years or even centuries in a relatively brief period with the assistance of machine learning. Furthermore, it will enable us to arrive at better-informed choices than we would have to if we had to rely just on experience and predictions [34].

Drug development is one of the numerous fields in which deep learning, a novel machine-learning method, has demonstrated outstanding results. Although the use of deep learning in pharmaceutical effect projection has only just been investigated, these algorithms have special qualities that could render them better suited for difficult challenges involving the simulation of drug responses employing chemical and biological information [35]. Current developments in deep learning have allowed computers to gather data from photographs like never before. Exciting fresh possibilities for drug recycling have arisen from the development of deep learning models utilizing large-scale collection of data [36].

4. Using AI in regenerative medicine

AI has emerged as a critical component in the execution of computational models and in silico investigations for healthcare purposes. It has several benefits over conventional therapeutic inquiry strategies, including quicker outcomes and reduced expenses. Numerous major tasks are now being undertaken to integrate AI into a variety of industries, including but not limited to healthcare, drugs, and medical care [37]. These initiatives seek to improve and expedite some procedures, including medication creation, illness diagnosis, and medical care, by utilizing AI. Researchers and practitioners believe that incorporating AI will lead to more precise and effective results, which will ultimately improve people's standard of living individually and in groups [38]. In particular, by automating processes like sifting through massive molecular and biological records and finding relationships and trends that human scientists would overlook, deep learning can hasten the discovery of regenerative medicines. By doing so, scientists may be able to create more potent treatments to target the underlying illness processes. It discusses a few of many significant areas in regenerative medicine where artificial intelligence may prove beneficial [39].

The chemical universe contains an enormous quantity of compounds, which presents advantages and difficulties for the search and creation of new drugs. Drug development in the setting of regenerative therapy is the procedure of locating compounds, biological products, or similar medicinal substances that can support tissue regeneration and operational restoration. The absence of modern technology hinders the creation of new medications. Since conventional drug research procedures need the synthesis and screening of several molecules to find possible therapeutic candidates, they can be costly and time-consuming [40]. Making sure that possible treatment options are both healthy and efficient is a key consideration in the medication development process. AI has become a potent instrument in the fight against these obstacles, able to anticipate which medicines are most effective for particular ailments by analyzing enormous collections of chemical components. Through the analysis of chemical compositions and characteristics, trends and correlations have been found, which can aid in the identification of viable medication ideas. Chemicals could be ranked in order of priority for more research and production using this data [41]. The drug goal, or the particular biological substance or route that a medicine wants to communicate with, could potentially be validated with the use of AI. Scientists can save valuable along with by employing AI to learn more about the purpose and prospective efficacy of the medicinal subject. By examining the chemical patterns and characteristics of possible medication prospects, it can also forecast their level of hazard. This may mitigate the chance of serious side effects by assisting in the earlier identification of any potential risks during the medication discovery phase [42]. AI can also help in the creation of novel compounds that are tailored for particular treatment uses. Additionally, it can make it easier to identify novel compounds that have a higher chance of being successful therapies for specific illnesses. Even though AI has the potential to greatly improve drug development management, scientists and physicians still need to deal with concerns with data quality, openness, and regulations. They can develop AI solutions and raise the efficacy and speed of drug research by tackling these obstacles [43].

5. Cellular therapy and AI

Cell treatment, a potentially exciting area of regenerative medicine, uses living cells to substitute or heal sick or wounded organs and tissues. It is predicated on the assumption that since cells can both divide and recover, they are perfectly suited to heal wrecked tissues and organs. Alternative therapies for several chronic diseases and injuries that are presently restricted or nonexistent could be revolutionized by cell therapy [44]. The application of stem cells to medical treatment represents one of its most exciting frontiers. Undifferentiated progenitors with the capacity to develop into several cell kinds are known as stem cells. They are available from several sources, such as adult and embryonic tissues as well as umbilical cord blood. Even though cell therapy has yielded encouraging leads to clinical studies, there are still many obstacles to be overcome to find the right cells, guarantee their security, and maximize their beneficial effects [45]. AI has a chance to completely transform cell therapy by allowing scientists to examine enormous volumes of data and gain fresh perspectives regarding the way cells function. AI's capacity to assist in determining which cells are optimal for a certain patient constitutes one of the main advantages of utilizing it in cell therapy. AI algorithms are capable of predicting which cells could probably be beneficial in curing a patient's illness by examining their genetic data and medical records. AI can also assist scientists in determining the best environments for cell growth [46].

One crucial stage in cell therapy that can have an enormous effect on the treatment's outcome is getting the cells to the target place. By streamlining the management process and guaranteeing that the cells arrive at the intended location, AI can enhance the transport of cells. To optimize therapeutic advantages, AI can also assist in determining the ideal dose and timing of cell distribution. It can also help in following the cells after they are delivered, analyzing their movement and existence, and identifying any negative consequences. This may help modify the therapeutic strategy and enhance patient results [47]. The application of AI in cell treatment has certain restrictions in addition to its possible advantages. A primary constraint is the caliber and volume of accessible data. For AI algorithms to forecast results with accuracy, vast volumes of high-quality information are needed. Unfortunately, patient information in the discipline of cell treatment is frequently sparse and varied, which makes it difficult to successfully train AI programs. Because AI models could be just as accurate as the information they have been taught, the precision of AI estimates may be impacted by flaws or irregularities in the information being analyzed. The intricacy of biological processes is a further drawback. The interactions between cells and tissues in cell therapy are extremely complex, which makes it challenging for many machine learning and deep learning algorithms to effectively simulate them [48].

6. Detection of skin cancer

The most common cancer among humans is skin cancer. Most cases of skin cancer are diagnosed visually, starting with a clinical test and potentially advancing to a biopsy, histological testing, and dermoscopic study [49]. The natural manifestation of skin concerns that cannot be detected sooner makes the identification of wounds and their scanning difficult. Several deep-learning neural networks and machine learning are available currently.

One of the most deadly malignancies for a person's life and well-being is lung cancer. Despite being the most frequently detected cancer overall, most lung cancer sufferers receive a more advanced detection [50]. The association between AI and the diagnosis of lung cancer is seen in several freshly published instances. The division technique for the neural network-based lung cancer models demonstrated good recognition efficacy in a case test [51]. After lung cancer, prostate cancer is the second-leading cause of cancer in men to be diagnosed. To determine whether a patient has prostate cancer, physicians have to examine the findings of central needle samples. AI models were developed to address issues arising from the growing responsibilities of physicians, labor shortages, and variations in the assessment of histopathology [52]. Breast cancer is a particularly widespread kind of malignancy in women and the primary source of cancer-related deaths among women worldwide. A statistical analysis indicates that the fatality rate from breast cancer has risen dramatically in all countries, although it has increased most in the less wealthy areas. The most effective approaches for avoiding and treating this type of cancer are through breast testing and enhanced diagnostic tools [53].

One of the most common malignancies worldwide is colorectal cancer. It is critical to identify and recognize patients as soon as possible, assess the efficacy of their therapies, and make precise prognostic predictions to reduce cancer incidence by increasing the lifespan of patients. AI has demonstrated significant potential in the clinical domain of colorectal cancer (CRC) in the past decade, thanks to growing omics and clinical data and ongoing machine learning development [54]. These tools have given scientists fresh techniques to identify high-risk patients and select individualized treatment plans. Gastric cancer is sixth in the world's cancer rates per year, making it a significant condition on an international scale. Due to its advanced phase of evaluation, gastric cancer has a significant fatality pace, making it the third-leading source of fatalities due to cancer globally in 2018 (784,000 deaths). Gastric cancer is double as common in men as in women [55].

AI has surfaced in the pharmaceutical sector as a prospective remedy for problems discovered by classical chemistry, which hinders the creation of new drugs. Computer-aided drug design (CADD) has profited from the rising usage of AI methods such as ML and DL due to advances in technology and the creation of powerful computers [56]. The in-depth understanding of clinicians could potentially improved by the automated AI capacities. The ability to monitor multiple lesions simultaneously, precisely define the volumetric tumor size as time passes, understand individual tumor outcomes by cross-referencing them to records of possibly endlessly numerous similar instances, and translate phenotypic to genotypic implications are among the many instances of the way these automated capacities might strengthen medical knowledge [57].

7. Limitations of AI

AI is capable of handling multitasking, nonlinear complicated interactions, and development. Considering that it is adaptable and capable of handling parallel processing of both quantitative and qualitative data. Its practical application has been demonstrated by numerous research findings from several disciplines [58]. AI is now used in medical and clinical settings in a variety of ways. It not only capitalizes on various aspects of clinical variety, but it additionally assists in correction. AI has enormous promise to transform and expedite the creation of regenerative medicines. By evaluating enormous molecular and genomic information that is incomprehensible to humans, AI can offer perspectives on a variety of topics, from improving drug development to improving tissue engineering and cellular therapy [59]. Even though AI has the potential to further exploration and progress in regenerative medicine, there are still many important technical problems that need to be resolved until these advances are extensively used. The absence of serious, accurate information required to train complex machine-learning algorithms is one of the main drawbacks. Complicated biological relationships involved in regenerative therapies are hard to adequately represent in statistics [60].

Furthermore, because of our incomplete knowledge of cellular and chemical processes, creating precise computer models that can mimic and anticipate cell behavior across time has enormous technical difficulties. Comprehensive research is necessary to validate AI algorithms and obtain legislative clearance; this process is time- and resource-consuming [61]. It is similarly crucial to tackle issues with data privacy, security, and bias as well as to provide fair and equal accessibility to fresh technologies. Furthermore, overcoming uptake barriers will be necessary to get physician buy-in for innovations that promise more efficient individualized treatment. To get over these challenges and turn artificial intelligence's theoretical promise in regenerative medicine into practical solutions that enhance patient results, a significant amount of continuing research is still required [62]. The development of suitable protections, supervision procedures, and rules for the application of AI in regenerative medicine requires collaboration between researchers, legislators, healthcare providers, and AI developers. The potential for improving and tailoring AI algorithms, particularly for regenerative medicine applications will rise as AI technology advances and further excellent information becomes accessible [63].

Future advancements in fields like robotics, computer goals, natural language interpreting, and machine learning may yield fresh perspectives that completely alter the method of creating and implementing regenerative medicine. When AI is combined with other cutting-edge technologies like genome editing, nanotechnology, and 3D bioprinting, it could result in previously unheard-of breakthroughs in the development of customized regenerative treatments. The future of AI-driven regenerative medicine is bright, provided the necessary legal and ethical guidelines are in place [64].

8. Conclusion

Because AI and ML can be applied in healthcare settings, the prospects of medical disciplines, particularly in the detection and therapy of cancer, look bright in this era of rapidly advancing technology. Faster guiding visualizations for particular therapies are made possible by AI, which will be essential in the future as the population grows. Researchers and technicians dare to enhance conventional ways of advancement because of AI's accuracy and precision. AI has brought something special to the research and therapy of anticancer drugs. Since human knowledge is limited, it might be challenging to develop the best course of action. According to this perspective, patients might overlook important therapy possibilities and their health may even worsen if doctors prescribe improper care. It can tailor each cancer patient's medication and offer significant data and knowledge that cannot be found through human recognition. AI has the potential to significantly accelerate the development of anticancer treatments by expediting the discovery of novel materials. Finally, AI-enabled disease modeling can help discover new treatment strategies for malignant cells and offer an understanding of the mechanisms underlying illness. To find patients who might benefit from regenerative therapies and to better tailor treatment regimens, AI can enhance predictive modeling. The creation of tailored medicine strategies based on a patient's genetic and medical data can be made possible by AI. AI can help with cell delivery and monitoring optimization as well as the identification of the best cell types for cell treatments. AI may be utilized to continually track patients to identify alterations and potential hazards. AI is able to offer patient training resources that are customized based on each patient's requirements and preferences. AI can increase traceability, and transparency, and improve evaluation of information to boost regulatory compliance. AI is also used in adjacent domains like immunotherapy, which can improve cancer therapies from the start. AI is anticipated to play a significant role in advancing human cancer research and therapy in the future. We anticipate that at some point in the future, AI will significantly alter medical technology.

Disclosure statement

The author declares no conflict of interest.

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