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Review on Revolutionizing Blood Cancer Treatment: Integrating AI with Carbon Nanotubes for Drug Delivery

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Abstract*— Advances in nanotechnology and artificial intelligence (AI) have revolutionized cancer research and treatment, including cancer treatment. Carbon nanotubes (CNTs), in particular, have shown great potential in drug delivery due to their unique properties such as high surface area, electrical conductivity, and biocompatibility. This article will discuss the current status, challenges, and future directions of AI-CNT integration in blood cancer research. The purpose of this article is to provide information on a review of routine tools used in hematology research. The purpose of this review is to explore the use of deep learning (DL) and machine learning (ML) in the treatment of blood tumors of all stages and types of hematological malignancies. Our goal is to develop actionable guidelines for further blood cancer research. Analysis; It is the result of database research in top databases, including PubMed, Science Direct, Springer, NCBI, and Elsevier journals. The backlog is carefully reviewed and compiled to create an authoritative and up-to-date version of the field. This article describes the properties of carbon nanotubes, explains their operating methods, and demonstrates their role in cancer diagnosis and treatment. Carbon nanotube-based drug delivery can improve the biodistribution of medical drugs and bind blood circulation, thus improving the effectiveness of the drug and reducing the dosage. Using AI to determine the best treatment for a patient's stage of cancer requires further research, as treatments such as chemotherapy can be problematic and repeatable, requiring risk assessment and mitigation planning.

Objective - The aim of this paper is to provide a comprehensive analysis of modern AI techniques used in the field of haematology. In particular, we highlight the use of AI-CNT for targeted drug delivery in hematologic malignancies and the application of AI to determine the best course of treatment based on the patient's cancer stage. Our goal is to explore the application of ML and DL techniques in the study of blood cancers. The purpose of this analysis is to map out possible directions for further blood cancer research.

Review method - This review article is the result of database research in top databases, including PubMed, Science Direct, Springer, NCBI, and Elsevier journals. The research focuses on research and literature review on the use of CNT and AI-assisted drug delivery in cancer research, using topics such as blood cancer, artificial intelligence, medicine, nanotechnology, CNT-based drug delivery, AI-assisted drug delivery. The backlog is carefully reviewed and compiled to create an authoritative and up-to-date version of the field. To ensure the best quality selected articles have been checked for publication integrity and accuracy.

Conclusion - Current literature indicates that AI applications in hematology have achieved notable success in screening, diagnosis, and treatment. However, there remains a need to optimize patient treatment pathways by predicting malignancy based on symptoms or blood records, an area that has yet to be thoroughly explored.

Index Terms - Blood Cancer, Artificial Intelligence, Targeted Therapy, Nanotechnology, CNT's based drug delivery, AI-Powered Drug delivery.

I. INTRODUCTION

Cancer is a major global health problem and the second most common cause of death in the United States [1]. Blood cancers such as multiple myeloma, leukemia, and lymphoma arise in the bone marrow or lymphatic system, unlike internal cancers. Blood cancer, also known as blood cancer, is a type of cancer that affects the blood, bone marrow and lymphatic system [2], [3]. They are a group of different diseases that include leukemias, lymphomas, and multiple myeloma. Current treatment options for blood cancer, such as antibiotics, radiation, and immunotherapy, have limited effectiveness and are often associated with serious side effects [1]. Therefore, new and effective treatments are urgently needed to improve patient outcomes. Carbon nanotubes (CNTs), in particular, have shown great potential in drug delivery due to their unique properties such as high surface area, electrical conductivity, and biocompatibility [5]. On the other hand, artificial intelligence can analyze big data, identify patterns and make predictions; this makes it an excellent tool for self-healing and correction [6], [7]. It has the potential to revolutionize leukemia treatment by improving the targeting and delivery of drugs, reducing side effects and improving patient outcomes [8]. This article aims to discuss the current status, challenges, and future directions of AI-CNT integration in leukemia treatment.

II. ARTIFICIAL INTELLIGENCE (AI) IN BLOOD CANCER

The field of cancer research and treatment, especially the treatment of blood cancer, has been transformed by artificial intelligence (AI). The ability of artificial intelligence (AI) to analyse massive volumes of data, spot trends, and make predictions has enhanced medication development,

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diagnosis, and customised treatment. MRI and CT scan images can be analysed by AI-powered algorithms to diagnose cancer earlier and more precisely than by human clinicians. AI can also be used to identify distinct cancer subtypes, allowing for more focused treatment and better patient outcomes. AI has also revolutionised medication development and discovery; furthermore, AI has had a major influence on AI-assisted personalised medicine [3].

A. Current Applications and Advances

Cytomorphology

Cytomorphology has been an important tool in hematology for over 150 years and involves examining the morphology of blood cells to diagnose blood cancers. However, this approach relies on human skill and is subject to change. Recent advances in digital microscopy imaging and machine learning (ML) technology can enable image processing, data analysis, and classification, improving reproducibility and accuracy [9]. Automated identification and identification of single cells have been successfully used to identify different types of AML [10], to differentiate between reactive patterns and myeloproliferative neoplasm (MPN) [11], and cervical cancer (TXHW) [12] ,[13]. Additionally, histology related to digital histology has become a powerful tool for cancer diagnosis by leveraging machine learning for whole slide images [14].

Cytogenetics

Cytogenetics, another diagnostic method, relies on analyzing and interpreting morphological features of chromosomes. Automated karyotyping has been available for over 30 years, but challenges persist, including identifying and selecting individual chromosomes, labeling and assigning them to the correct position in the karyogram, and overcoming difficulties in differentiating between similar chromosomes [15]-[24].

Immunophenotyping

Immunophenotyping, which uses multiparameter flow cytometry (MFC) to analyze cells based on antigen expression patterns, is also important for the diagnosis of leukemias and lymphomas. However, this approach is error-prone and relies on human creativity. Automated methods have been developed to reduce variability and improve reproducibility [25]-[38].

Molecular Genetics

Molecular genetics, which involves analyzing DNA sequences, has entered the realm of big data with the introduction of high-throughput sequencing techniques. Machine learning (ML) and deep learning (DL) methods have been applied to perform tasks impractical for humans, including recognizing DNA sequence patterns, variant calling, and variant effect prediction and classification [28], [30]. ML algorithms have also been applied to integrate mutational data, peripheral blood values, and clinical data to differentiate various bone marrow disorders [35].Overall, AI technologies have revolutionized the field of cancer research and treatment, improving diagnosis, drug development, and personalized treatment. However, challenges persist, and further research is needed to overcome these hurdles and fully realize the potential of AI in cancer diagnostics.

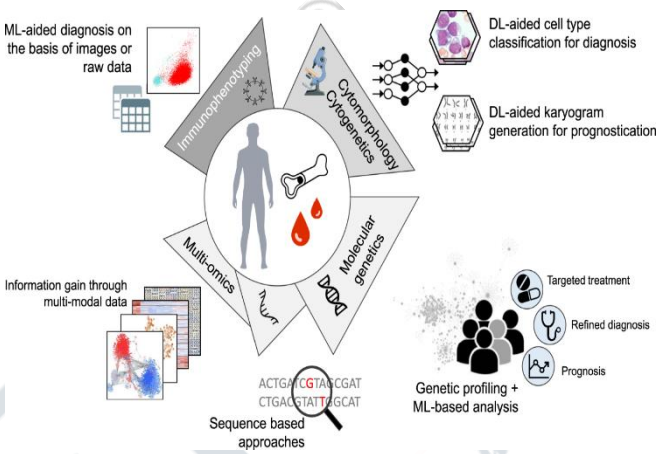

Fig. 1. The core of the diagram showcases existing and forthcoming diagnostic techniques and methodologies, while the outer section delineates diverse data formats and the prospective clinical significance of machine learning (ML) based applications and analyses. Deep learning (DL) is denoted as "DL" and machine learning as "ML."

III. CNT'S FOR DRUG DELIVERY TO TREAT BLOOD CANCER

Carbon nanotubes (CNTs), a distinctive type of one-dimensional nanomaterials, have attracted considerable interest due to their unique properties, adaptable functionalization chemistry, and compatibility with biological systems over recent decades. Various techniques can be employed to modify CNTs for specific purposes. CNTs have found utility in diverse biomedical applications, serving as carriers at the nanoscale, particularly in cancer diagnosis and treatment. Through diverse methods, such as peptide, antigen, and nucleic acid delivery, CNTs demonstrate remarkable efficacy in transporting payloads to cancer cells. This review encapsulates the characteristics of CNTs, delineates methods for their functionalization, and elucidates their roles in both cancer diagnosis and therapy.

A. Properties of CNT's

Carbon nanotubes (CNTs) were discovered by Oberlin in 1976 [39]. The main techniques are arc discharge, laser ablation and chemical vapor deposition (CVD) [40]. Carbon nanotubes are divided into single-walled (SWCNT) and multi-walled (MWCNT). SWCNTs consist of single graphene cylinders, while MWCNTs consist of multiple concentric graphene layers [41], [42]. Multi-walled carbon nanotubes include double-walled (DWCNT) and triple-walled (TWCNT) subtypes [43] with inner diameters

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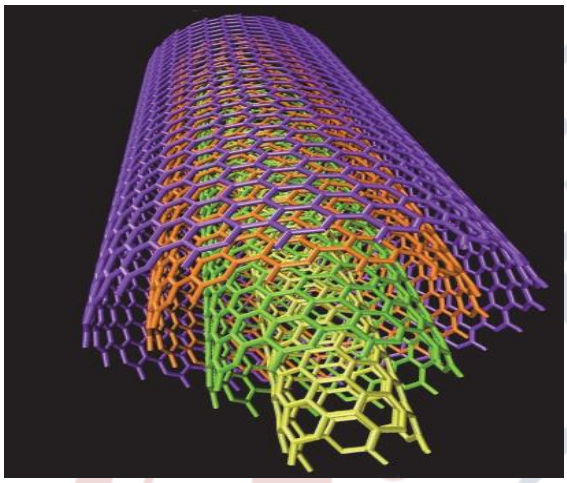
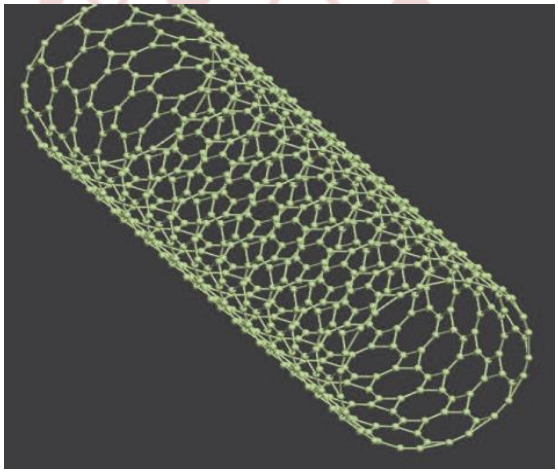
of 1-3 nm and outer diameters of 2-100 nm [44]. The wall thickness of SWCNTs is 0.2-2 nm [45] and they have a higher aspect ratio than MWCNTs. The large internal diameter of multi-walled carbon nanotubes provides more space for drug delivery, and their shells can be functionalized without damaging the walls values [46], [47]. Oxidation with strong acids shortens carbon nanotubes and adds carboxyl groups, increasing water solubility [48]. The reaction between the outer wall and the tip increases the solubility [49], [50], which is important for biocompatibility [47]. Functionalized carbon nanotubes (f-CNTs) can integrate a variety of active molecules such as peptides, proteins, and nucleic acids. The high aspect ratio, large surface area, mechanical strength and electrical conductivity of carbon nanotubes make them ideal for biomedical applications [51], [52]. However, pristine carbon nanotubes are hydrophobic, limiting their biomedical applications due to their poor solubility and high cytotoxicity of residual metal catalysts. Functionalization should make carbon nanotubes soluble and biocompatible [41].



(a)



(b)

Fig. 2. Conceptual diagrams of single-walled carbon nanotubes (SWCNTs) (a) and multiwalled carbon nanotubes (MWCNTs) (b).

B. Applications of CNT's In Cancer Therapeutics

The only treatment for cancer in the early stages is radical resection. Advances in biotechnology have recently led to new cancer treatments, but an effective method for delivery of chemotherapeutic drugs is still needed [53], [54]. Over the years, various drug delivery systems such as liposomes, natural and synthetic polymers, and nanoparticles have been evaluated for the delivery of doxorubicin (DOX) and paclitaxel (PTX) and other drugs. Liposomes and polymeric materials are widely used, but the special properties of non-functional materials such as carbon nanotubes are often neglected. Carbon nanotubes are suitable carriers for drug delivery due to their thermal conductivity, rigid structure, high specific surface area and excellent biocompatibility. It increases immunity in tumor cells. This article reviews the use of carbon nanotubes in cancer therapy.

C. CNTs in Cancer Chemotherapy

Overcoming biological barriers to effective chemotherapy is important, including liver and kidney clearance, hydrolysis, enzymatic degradation, endocytosis, and lysosomal degradation. Chemicals are often contaminated, unsafe and toxic, which affects their effectiveness. Carbon nanotube-based carriers can improve drug biodistribution and blood circulation, thus improving drug efficiency and reducing dosage. For example, Loaded DOX into branched PEG-functionalized SWCNTs to prolong blood circulation and found that DOX could be delivered to tumors and eliminated through renal excretion [55].As of now scientists designed PEG-grafted carbon nanotubes to improve PTX loading and promote its delivery for 40 days in vitro [56]. Researchers have also modified SWNTs to achieve better delivery, such as EGF-mediated SWCNTs delivery of cisplatin [57]. Additionally, multiwalled carbon nanotubes can be used for thermal ablation and can induce high temperatures to destroy cancer cells.

CNTs in Drug Delivery

Toxicity of chemotherapeutic agents is mainly due to non-selective routine administration, poor solubility and inability to cross cellular barriers [58]. Recent research has focused on carbon nanotube-based delivery systems containing functionalized carbon nanotubes, targeting ligands, and antibodies. These systems can bind many drugs and cross the cell membrane due to their high surface area [57], [59], [60]. Carbon nanotubes can target specific receptors on cancer cells to achieve receptor-mediated endocytosis and deliver effective anticancer drugs, reducing cytotoxicity and serious side effects [57]. Compared to traditional carriers, single-walled carbon nanotubes have higher carrying capacity. Figure 4 shows the single-walled carbon nanotube-mediated delivery system for cancer therapy and demonstrates the potential of carbon nanotubes for drug delivery.

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Photothermal Therapy

Photothermal therapy is a non-invasive cancer treatment that uses near-infrared (NIR) radiation to heat carbon nanotubes injected into cancer cells, causing cell death [61], [62]. This method reduces side effects of healthy soft tissues [63], [64]. Carbon nanotubes absorb light well in near-infrared and radiofrequency radiation [65], [66]. The length of carbon nanotubes is important in terms of energy transfer and cell damage [67]. Photo-thermal therapy combined with chemotherapy and gene therapy can improve the outcomes of cancer treatment [68]. Targeted carbon nanotubes can be coated with ligands such as monoclonal antibodies or peptides for cancer therapy [68], [69]. Carbon nanotubes heated to 50–70°C by laser irradiation can kill cancer cells without affecting healthy cells [70], [71].

Delivery of Immuno-Therapeutics

Studies are being carried out to use carbon nanotubes in cancer treatment. Tumor-mediated vaccines (TCVs) use inactivated cancer cells or dendritic cells presenting tumor antigens to activate the immune system against the tumor [72]. Oxidized MWCNTs can be combined with tumor lysate proteins to enhance TCV activity. Vera et al. It has been shown that single-walled carbon nanotubes can be used as antigen presentation devices to enhance the response to weak antibody peptides [73]. The combination of Wilm's tumor protein (WT1) with a wall of carbon nanotubes helps support immunity and effective treatment by creating antibodies against many cancers.

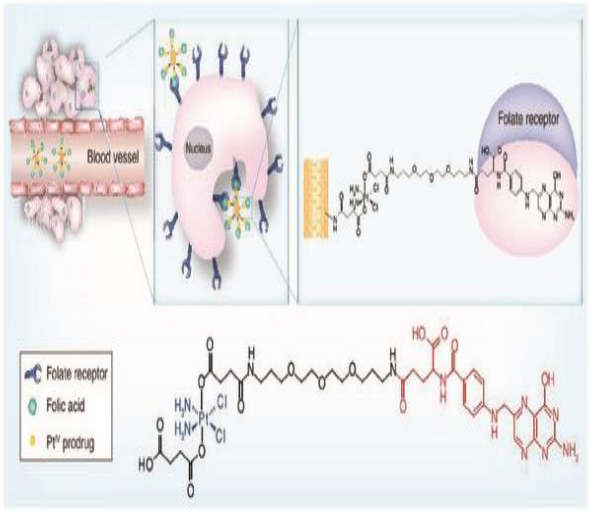

Fig. 3. Folate-mediated cancer targeting using single-walled carbon nanotubes conjugated with platinum-containing anticancer drug and its subsequent endocytosis [51].

IV. INTEGRATION OF AI AND CNT'S FOR DRUG DELIVERY TO TREAT BLOOD CANCER

Analysts have long focused on the development and use of micro-robots in the pharmaceutical industry. These nanomachines have been described for different medical functions, including delivering in situ sedation for counting, targeting disease cell layers, and performing microsurgery. Despite ongoing challenges in fabric design, manufacturing, accessibility, and biocompatibility, the decisions highlight the importance of nanorobotics [74]. The following considerations relate to the use of radiolabeled nanomotors for in vivo imaging, which may be more accurate and stable. Additionally, PET has been used to quantitatively monitor nanomotors, improve point-of-care, track dynamic fusion points, and pave the way for drug use in clinical practice [75]. Fabricated Nanorobots Many insights have emerged due to advances in bio-nanotechnology and design [76]. Researchers are exploring the use of computerization in atomic manufacturing, where artificial intelligence can monitor the behavior and movement of nanorobots [77]. Advanced nanorobotics have demonstrated controlled drug delivery and effective nanocommunication by leveraging AI-based animations and demonstrations [78]. The pseudonervous system (ANN) of these nanorobots is an important part to improve and expand their ability to identify tumor cells to focus on tissue stability [79], [80]. Additionally, after examination of the tumor, the feeling of swelling turned out to be a useful concept in calculating intracellular drug products. The direct mapping required to detect accurate measurements of intracellular organization can be generated from puffy samples [79], [81].

V. CONCLUSIONS AND FUTURE RESEARCH DIRECTIONS

Through early detection and prediction of hematopoietic malignancies, the survival rate of patients can be greatly improved and the mortality rate can be greatly reduced. However, due to the complexity of medical data, it needs to be examined in detail to reveal important features and uncover hidden patterns. Artificial intelligence is required to manage large amounts of data. However, data augmentation, transformation, and transfer learning can help solve the problem of limited data for AI applications. This literature review discusses recent advances in deep learning (DL) and machine learning (ML) in cancer treatment, including all stages and categories of hematological malignancies. Because deep learning is new and requires larger data sets, which are often limited in the healthcare industry, machine learning techniques are used more than deep learning. ML and DL performance varies by data type and application. Hematological malignancies are particularly difficult to detect and diagnose because they are difficult to detect early. For this reason, in many studies, less importance has been given to these stages and predictions during the clinical phase. Because treatments such as chemotherapy may have side effects and relapses, risk assessment and mitigation strategies are important and further research is needed. Acute myeloid/lymphocytic leukemia is the most common and fastest growing cancer, followed by lymphoma. Acute

leukemia, on the other hand, is more difficult to treat and less studied because it grows slower and does not cause symptoms until later in life. Incorrect diagnosis may cause delay in diagnosis and decrease treatment results. Predicting risk and avoiding late diagnosis therefore relies heavily on predictive algorithms that extract disease and symptoms from clinical data. Although many studies have used gene expression, flow cytometry, or clinical imaging to predict hematological malignancies, none have relied on patient complete blood count (CBC) results to identify or predict hematological diseases. CBC is a popular diagnostic test used to diagnose leukemia, so further research in this area would be helpful.

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