

Advancements in anticancer Drug development: Challenges and solutions

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Abstract

A local disease that may spread and affect other organs or vital functions is what cancer is, an occurrence of uncontrolled cell growth that results in the formation of an abnormally developing tumour. Cancer is one of the most deadly illnesses in modern times, taking countless lives every year. Variations in the illness throughout the world, the influence of accessible medical facilities, and other socioeconomic concerns have all affected the successful care of this disorder. In this article, review the various literature's study on the challenges and solution in anticancer drug development. From the review it concluded that development of anticancer drugs remains challenging due to high costs, long timelines, and frequent failures. While progress has been made, obstacles like toxicity and poor efficacy persist. Machine learning (ML) is transforming drug discovery, especially for natural product (NP)-derived therapies, yet more ML tools are needed. Nanocarrier advancements, combined with ML, enhance drug delivery and reduce side effects. Novel heterometallic complexes and heterocycles further improve treatment. Integrating NP-based chemotherapies with deep learning offers promising results, emphasizing the need for innovation, collaboration, and technology-driven approaches to develop more effective cancer therapies.

Keywords: Anticancer drug development, Machine learning (ML), Natural product (NP), Drug discovery and delivery, Cancer treatment, etc.

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1 Introduction

The condition known as cancer is complicated and is brought on by malignant cells that divide and spread throughout the body all the time. It is also known as a category of disorders with distinct altered dynamics and behaviours. Prostate, colon, skin, lungs, breast, and many other parts of the body may all be affected by cancer. Sustainability, societal development, and the viability of all statuses are important factors in medical research and innovation when it comes to predicting the danger of cancer in the future [1]. Anticancer medication development is a priority in order to give more effective therapy. Because cancer is a collection of illnesses that are not under the control of the cancer cells' numerical increase. Historically, anticancer medications have been an important part of the many cancer therapy approaches [2].

The disease known as cancer occurs when cells proliferate out of control, creating tumours that grow abnormally and have the potential to spread to other organs or critical systems, affecting their functionality. Cancer is considered a multifactorial illness since it is caused by genetic mutations, pollution, dietary toxins, viruses, chemicals, and ionising radiation, among other determining factors [3]. The production of two genetically identical cells is ensured by the strict regulation of cell division by a number of evolutionarily conserved cell cycle regulatory systems. Many people die from cancer every year, making it one of the deadliest diseases in modern history. This illness's global variances, the influence of accessible medical facilities, and other socioeconomic conditions have all affected how this disease should be managed [4], [5].

A. Natural products significance in Anticancer drugs

Natural products' diverse and complex chemistry, which has evolved over millions of years via natural selection, makes them important in the hunt for anticancer medications. For many years, natural materials derived from plants, microbes, and marine life have provided a plentiful supply of lead compounds for the production of pharmaceuticals, particularly anticancer drugs [6]. These compounds are well suited to target specific molecular pathways that contribute to the development of cancer since they often possess unique bioactive properties and complex molecular scaffolds. Furthermore, screening and optimising processes may access a vast chemical diversity pool present in natural products to identify novel treatment options with enhanced potency or selectivity [2].

B. Challenges in Unsustainable Sourcing

A lot of complex ethical, social, and environmental issues are brought up by non-sustainable sourcing in the development of anticancer drugs. Unsustainable sourcing methods have the potential to decrease biodiversity and cause major ecological impact [7]. Examples include over-harvesting medicinal plants and indiscriminately removing natural resources from delicate ecosystems. This habitat loss not only endangers plant and animal species, but it also puts medicinal plant populations at risk of extinction, which might make the present search for novel drugs more difficult [8]. Negative social and economic effects may also result from unethical sourcing, especially in places where populations who rely on

natural resources for their lives dwell. Overuse of medicinal plants may cause social discontent about resource allocation and access, worsen poverty, and upend traditional knowledge networks [2].

C. Economic challenges in healthcare

Significant development and research as well as financial backing are necessary when creating any form of product. However, lack of accessibility, excessive expense, and stifled innovation make the task more difficult. The cost of development is increasing daily due to the long timetable and high failure rate of newly developed techniques. Moreover, clinical studies, clearances, and other very demanding procedures must be completed by the original testaments. It continually maintains the chronology [9]. The cost of the product is also a barrier for the average person, making it more difficult for them to get these therapies. It is an economic challenge to go through the whole process of studying their medicine, producing a solution, and then making it affordable and sustainable for regular people [2].

D. Challenges in Advancing Sustainability Goals

Advancement of sustainability goals in anticancer drug research is difficult; there are several complex obstacles that need concerted efforts from stakeholders across numerous sectors. Reducing the obstacle to sustainability and profit in the pharmaceutical industry is the primary problem while producing anticancer medications. Because they fall under the green energy principles, distribution networks and local medicine manufacturing may help with this issue [10]. However, putting these ideas into practice with a viable business plan and educating healthcare professionals about the emerging technologies might be difficult. Furthermore, because it might take a lot of time and money to change and reverse anything on a large scale, the legislative environment makes it challenging to incorporate sustainable ideas into the continuing regulatory management system [11].

E. Drug Resistance in Cancer Treatment

Drug resistance is one of the most challenging issues to address when using anticancer medications to treat cancer. It happens when the cells adjust to the alterations, become less aggressive towards the cancer cells, and the rate of death falls. Genetic mutation, DNA repair processes, tumour microenvironment, drug efflux, and other factors are among the mechanisms behind medication resistance [12]. The last several decades have seen the introduction of a variety of therapeutic approaches for these processes, including immunotherapy, combination therapy, and adaptive therapy. However, despite these sophisticated therapeutic approaches, it still reduces the effectiveness of therapy. The aforementioned treatments have little effect on cancer cells that are primary resistant [13]. It may happen because of genetic variation or because the tumour cell previously included drug-resistant subpopulations. Conversely, acquired resistance occurs as a result of the selection pressure that is established during therapy. Professionals in medicine are now testing novel methods via a variety of medical trials and use biomarkers to anticipate resistance in advance [14].

F. Access to Anticancer Drugs

One crucial component of cancer treatment that presents difficulties worldwide is equitable access to anticancer medications. Access discrepancies may be caused by a number of things, such as legislative barriers, healthcare infrastructure, and economic differences. Many patients have financial obstacles due to the high cost of many anticancer medications, especially targeted treatments and immunotherapies [15]. Patients and healthcare systems are both affected financially, which often forces them to make tough decisions about how affordable treatments may be. Access issues are made worse in low-resource areas by a lack of specialised cancer facilities and a limited healthcare infrastructure [16]. Unfavourable results for patients in these areas are caused by insufficient treatment choices, delays in diagnosis, and a shortage of qualified healthcare providers. International efforts are being made to improve access to necessary anticancer drugs in order to alleviate these inequities [4]. Initiatives include assistance for low-income nations to improve their cancer care infrastructure, pricing negotiations with pharmaceutical corporations, and the creation of reasonably priced generic versions of important anticancer medications. Additionally, studies into telemedicine and cost-effective treatment methods seek to reach underprivileged groups with cancer care [17].

2 Literature Review

(Das & Agarwal, 2024) [18] To far, several phytochemicals have been used in the development of novel cancer treatments. The discovery of novel anti-cancer leads is a goal of pharmaceutical corporations and academics worldwide, and phytochemicals are a promising source in this pursuit. At the same time, because of their efficiency, reduced time-consuming nature, and cost-effectiveness, computational approaches such as virtual screening (VS), molecular dynamics (MD), pharmacophore modelling, Quantitative structure-activity relationship (QSAR), network biology, and machine learning (ML) have grown in popularity in recent years. In light of this, the current study compiles data on plant-based compounds found by in silico cancer lead acquisition strategies.

(Chunarkar-Patil et al., 2024) [19] Underlines the importance of natural products in the drug development process and explores the potential for collaboration between them and computational methods. Withaferin A and betulinic acid are two instances of in vitro and in vivo research that have shown the shift from computational to experimental validation. From preclinical research to clinical trials, the road towards medicinal uses has been shown by clinical studies of substances like silvestrol and artemisinin. Additionally, the difficulties and constraints in creating natural compounds as possible anti-cancer medications are discussed in this article. Additionally, expanding the anticancer potential of natural products may be possible via the combination of deep learning and artificial intelligence with conventional computational drug development techniques.

(Gach-Janczak et al., 2024) [20] For many years, chemists and pharmacologists have been actively searching for novel anticancer medications, either by screening hundreds of synthetic molecules or by isolating chemicals with deadly qualities from plants. Potential novel anticancer treatment candidates must be able to stop the growth of cancer cells and/or cause them to undergo apoptosis without seriously

harming healthy cells. While long-term study led to the discovery of certain anticancer chemicals, others were found by chance. A short history of the creation of the most significant classes of anticancer medications is provided in this article, emphasising the fact that each of them has a wide range of adverse effects.

(Tadesse et al., 2023) [4] Summarising previously published publications about current developments in anticancer medication discoveries was the goal of this research. Many discoveries are found via searches and categorised as plant-derived advancements, chemical compounds with in vitro or in vivo cytotoxic drug development, repurposing advances, and anticancer drug targets. In this overview, several recent developments in anticancer drug discovery are summarised based on a range of scholarly papers. Plant-derived breakthroughs in cancer therapy, certain pharmaceuticals repurposed for cancer treatment, prospective and clinically supported pharmacological targets for anticancer drug binding, and, lastly, advancements in new chemical compounds in the field of cancer therapy are discussed under this wide subject.

(Alqosaibi, 2022) [21] Heart disease is the leading cause of mortality worldwide, with cancer coming in second. To address this illness, many strategies have been devised, including as chemotherapy, radiation treatment, and surgery. Certain cancer cells may withstand apoptosis and become resistant to chemotherapy, despite the fact that its main purpose is to regulate cell division and cause cell death. Chemotherapy might have more negative consequences than positive ones, and the side effects are sometimes unbearable. Additionally, there is a great need for a dependable delivery system that guarantees prompt and precise treatment targeting since the stability and bioavailability of medications used in chemotherapy are important concerns that need to be addressed. We go over the many kinds of nanocarriers, their characteristics, and the latest developments in formulations in this overview, along with the pertinent benefits and drawbacks of each.

(Lu & Lu, 2020) [22] Developing and discovering high-quality anticancer drugs is more challenging and demanding than ever before. Overall, we need to rethink and reorganise biomedical, pharmacological, technological, and economic issues. While we have come a long way, there are still many problems and challenges from the past. This article presents interdisciplinary viewpoints on the discovery and development of anticancer drugs in an effort to address such types of biological therapeutic challenges and dilemmas.

(Singh et al., 2016) [23] Numerous signalling events are involved in the intricate process of carcinogenesis. Because of their pleiotropic properties, which allow them to target these events in a variety of ways, phytochemicals are the best candidates for the creation of anticancer drugs. The development of lead candidates from phytochemicals that may prevent or slow the spread of cancer without causing any negative side effects is underway. Numerous phytochemicals have both in vitro and in vivo anticancer properties. The action mechanisms of these lead phytomolecules on cellular and nuclear components implicated in carcinogenesis are discussed in this article. There has also been discussion of the clinical development of anticancer phytomolecules and druggability factors.

3 Conclusion

In conclusion, the development of anticancer drugs remains one of modern medicine's most significant challenges, marked by high costs, lengthy timelines, and a high failure rate. Despite considerable progress, the path from preclinical discoveries to clinical approval continues to be fraught with obstacles such as lack of clinical efficacy, toxicity, and unfavorable physicochemical properties. However, the integration of machine learning (ML)-based approaches in drug discovery, particularly for natural product (NP)-derived anticancer agents, offers promising opportunities. While existing databases like NPACT and AfroCancer are crucial, the need for more publicly available ML tools tailored to NP-based drug discovery is evident. Moreover, advancements in nanocarriers for drug delivery, combined with ML algorithms, enhance drug bioavailability and cytotoxicity while reducing side effects. Emerging compounds, such as novel heterometallic complexes and heterocyclic substances, further improve therapeutic outcomes. These developments highlight the growing potential of merging traditional natural product-based chemotherapies with cutting-edge technologies, such as deep learning, to improve cancer treatment efficacy. The future of anticancer drug development lies in continuing innovation, fostering collaboration, and embracing new technologies to create more precise, effective therapies for cancer patients.

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