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Innovative Cancer Treatment Methods: Present Perspectives and Emerging Difficulties

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Abstract

Millions of people die from cancer each year, and while medical science has made great strides, there are still many problems that need to be resolved before cancer treatment can be improved. Because of this, oncological research is working hard to develop novel, effective medicines that can lessen the serious side effects brought on by current medications. Different technologies are either already being used in clinical settings or are being tested in clinical studies. While bioengineering of extracellular vesicles and cells obtained from patients has made it possible to construct ad hoc systems and univocal targeting tactics, Nanomedicine is helping to develop biocompatible materials for both diagnostic and therapeutic applications.

Keywords: Cancer; Nanomedicine; Extracellular vesicles; Targeted therapy; Immunotherapy; Gene therapy.

Introduction

One of the major causes of death in the world is cancer, and during the past ten years, numerous research projects have concentrated on developing novel treatments to lessen the adverse effects of existing ones. As cancer progresses, tumours become extremely heterogeneous, resulting in a mixed population of cells with a variety of molecular characteristics and therapeutic responses. This variability, which is crucial to the establishment of resistance phenotypes encouraged by selection pressure upon treatment delivery, can be observed both at the geographical and temporal levels. Typically, cancer is viewed as a single, universal disease, and tumours are viewed as an entire cell population. Therefore, a thorough understanding of these complicated phenomena is crucial for creating effective and exact designs [1].

In order to administer traditional chemotherapeutic medications in vivo, increase their bioavailability and concentration around cancer tissues, and enhance their release profile, Nanomedicine provides a flexible platform of biocompatible and biodegradable systems. Nanoparticles can be used in a variety of processes, from therapy to medical diagnosis. Extracellular Vesicles (EVs), which are involved in the formation of cancer, the change of the microenvironment, and the spread of metastatic disease, have recently attracted a lot of attention as effective drug delivery systems. Due to their anti-proliferative and pro-apoptotic qualities, numerous phytochemicals and natural antioxidants have lately been used as adjuvant medicines in the fight against cancer.

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Another type of cancer treatment known as targeted therapy focuses on one specific area, such as the intracellular organelles or tumours vasculature, while sparing the surrounding tissue. This significantly improves the treatment's specificity while lowering its disadvantages. Another potential possibility is based on gene therapy and the production of genes that cause apoptosis and tumour suppressors of the wild type, or the targeted silencing mediated by siRNAs, which is now being tested in several clinical trials across the globe. By allowing for the localization of treatment in extremely small and precise locations, thermal ablation of tumours and magnetic hyperthermia are creating new possibilities for precision medicine. These techniques may serve as an alternative to more intrusive procedures like surgery [2]. Additionally, emerging disciplines like radionics and pathomics are assisting in the creation of creative methods for gathering massive amounts of data, developing novel therapeutic approaches, and accurately predicting patient responses, clinical outcomes, and cancer recurrence. Together, these approaches will be able to offer cancer patients the greatest individualized treatments, showing the value of fusing many fields to achieve the best results. Different approaches to cancer diagnosis and therapy and their current status in the clinical context will be discussed, underscoring their impact as cutting-edge anti-cancer approaches. These newly proposed methods that are currently under investigation at the research stage should overcome the limitations of conventional therapies [3].

Discussion

Due to their small size and high surface-to-volume ratio, nanoparticles (which range in size from 1 nm to 1000 nm) have unusual physicochemical characteristics. In cancer treatment, biocompatible nanoparticles are utilized to get around some of the problems with traditional therapy, like the poor specificity and bioavailability of medications or contrast agents. Therefore, the active drugs' solubility and biocompatibility, as well as their stability in body fluids and duration of retention in the tumour vasculature, will all be improved by encapsulating them in nanoparticles. Additionally, nanoparticles can be created to be highly selective for a particular target and to release the medication under controlled circumstances in response to a predetermined stimulus [4]. Thermo ox, a liposomal formulation that can release doxorubicin in reaction to a rise in temperature, is an example of this. For diagnostic applications, inorganic nanoparticles are typically used as contrast agents. Quantum dots are among them; they are tiny, light-emitting semiconductor Nanocrystals with unusual electrical and optical characteristics that make them extremely luminous, resistant to photobleaching, and sensitive for detection and imaging. They may be effective theranostic tools when combined with active substances. In recent work, an anti-HER2 antibody was coupled to quantum dots coated with Poly Ethylene Glycol (PEG), which were then localized in particular tumour cells.

The major purpose of organic nanoparticles is to transport medications. Although both liposomes and micelles are composed of phospholipids, their morphologies are different. Liposomes are spherical, lipid-bilayer-containing particles that resemble the shape of cell membranes. Hydrophobic medications can either be accommodated in the bilayer or chemically bonded to the particles; however, they are primarily utilized to encapsulate hydrophilic

pharmaceuticals in their watery core. Instead, micelles have a hydrophobic core that can encapsulate medications that are also hydrophobic [5]. The first nanoparticles to receive FDA approval were called "Doxil," which were PEGylated Liposomes loaded with Doxorubicin and used to treat Kaposi's sarcoma linked to AIDS. With this formulation, doxorubicin's adverse effects are significantly reduced. Since then, the FDA has approved several liposomal formulations for cancer treatment, including Myocet and DaunoXome. Based on the biogenesis of extracellular vesicles, two kinds are distinguished. In more detail, shed Micro Vesicles (sMVs), with a typical size of 50 nm-1,300 nm, are present in almost any extracellular bodily fluid and are responsible for the exchange of molecular materials between cells. Exosomes are small vesicles with an average size of 30 nm to 150 nm that are released from endosomes in physiological and pathological conditions. Exosomes have a role in the growth and spread of cancer. Exosomes play a role in the growth and spread of cancer, in the bidirectional communication between tumour cells and surrounding tissues, and in the development of the milieu required for the establishment of pre-metastatic niches and the evolution of the metastatic disease.

The human body is subjected to a number of exogenous insults on a daily basis, including tobacco smoke, air pollution, and Ultraviolet (UV) rays, which cause the body to produce reactive species, particularly oxidants and free radicals, which are in turn responsible for the development of many diseases, including cancer. In addition to being naturally produced inside our cells and tissues by mitochondria and peroxisomes as well as from the metabolism of macrophages during normal physiological aerobic processes, these molecules can also be produced as a result of the clinical administration of medications [6]. DNA, lipids, and other bio-macromolecules, including chromosomal abnormalities, DNA double-strand breaks, and necrosis, can all be harmed by oxidative stress and radical oxygen species. Our body contains defences against these chemicals, but they are occasionally unable to stop the significant harm they do. Recently, studies on the functions of the physiological enzymes Superoxide Dismutase (SOD), Catalase (CAT), and Glutathione Peroxidase (GP) have been added. These studies aim to introduce natural antioxidants like vitamins, polyphenols, and plant-derived bioactive compounds as preventive agents and potential therapeutic drugs. These compounds are present in many plants and spices and have anti-inflammatory and antioxidant activities. Vitamins, alkaloids, flavonoids, carotenoids, curcumin, berberine, quercetin, and many more substances have been screened in vitro and tested in vivo and have been offered as a complementary therapy for cancer due to their notable anti-proliferative and pro-apoptotic effects.

Despite the benefits of employing natural medicines, it is still challenging to implement them into clinical practice because of their low bioavailability and/or toxicity. Traditionally used in Southeast Asia, curcumin is a polyphenol molecule with anti-inflammatory, antioxidant, chemopreventive and therapeutic properties that are derived from turmeric (Curcuma longa). At the effective therapeutic levels, it has been demonstrated to have cytotoxic effects on a variety of tumour types, including brain, lung, leukaemia, pancreatic and hepatocellular carcinoma, with no negative effects on normal cells. Numerous cellular pathways can be altered by curcumin, but its biological features, and consequently the length of the course of treatment and the most effective therapeutic doses, are still poorly understood. This molecule is unstable, poorly soluble in water, and highly lipophilic. To increase its bioavailability, various methods and particular carriers, like liposomes and micelles, have been created. There are now 24 active clinical trials using curcumin, and 23 have already been finished. By attaching to cellular receptors and disrupting numerous signalling pathways, the polyphenolic flavonoid quercetin, which is present in fruits and vegetables, has been shown to be useful in treating a number of tumours, including breast, liver, colon, prostate, and lung cancers. It's interesting that research has revealed that it works well in conjunction with chemotherapy drugs as well. Seven clinical trials are active at the moment, and four have been finished [7].

The limited specificity of chemotherapeutic medicines for cancer cells is one of the major issues with traditional cancer therapy. In actuality, the majority of medications cause serious side effects by acting on both healthy and sick tissues. A lot of work is being done by researchers to develop a means to focus exclusively on the chosen spot. Due to their propensity to collect more in tumour tissues as a result of their increased permeability and retention impact, nanoparticles have attracted a lot of attention. Passive targeting is a technique that makes use of the small size of nanoparticles, the leaky vasculature, and the poor lymphatic drainage of cancerous tumours. However, passive targeting can lead to Multidrug Resistance and is challenging to control (MDR).

On the other hand, active targeting increases the absorption by tumour cells by focusing on a set of overexpressed receptors. For instance, ligands can be used to functionalize nanoparticles so that they bind a specific cell type or subcellular location without any doubt [8]. It is possible to use a variety of ligands, including small compounds, peptides, proteins, aptamers, and antibodies. Small chemicals like folic acid and biotin have overexpressed receptors in tumour tissues. In order to specifically target ovarian and endometrial cancers, a number of Nanocarriers have been functionalized with folic acid. For example, folic acid-conjugated polyethylene glycol-poly(lactic-co-glycolic acid) nanoparticles delivering docetaxel increased drug uptake by human cervical carcinoma cells. Simple conjugation chemistry can be used to attach small ligands to nanoparticles because they are inexpensive.

Conclusion

Cancer therapy research has made incredible strides in recent years toward more effective, accurate, and minimally invasive cancer therapies. While targeted therapy and Nanomedicine have improved the biodistribution of new and tested chemotherapy medicines around the targeted tissue, other approaches, including gene therapy, siRNA delivery, immunotherapy, and antioxidant compounds, have given cancer patients additional options. On the other hand, tumour excision methods including thermal ablation and magnetic hyperthermia show promise. In order to improve prognosis and outcome, radiomics and pathomics techniques assist in the administration of large data sets from cancer patients. The contemporary landscape of cancer research is complex; giving numerous opportunities for therapy improvement that take into account both patient recovery and overall wellbeing.

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