Fluid Mechanics in Action: Real-Life Application in Cancer Treatment

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Abstract

The use of fluid mechanics in cancer treatment has emerged as a promising field of research in recent years. This approach uses fluid dynamics principles to design and optimize drug delivery systems for cancer therapies. By understanding the behavior of fluids within the body, researchers are able to develop more effective methods for delivering drugs directly to cancer cells, while minimizing damage to healthy tissues. This technology offers a new frontier in the study of cancer, as it provides a highly controlled environment to investigate the behavior of cancer cells and their response.

Introduction

In Physics, fluid dynamics refers to the study of fluids in motion. Fluid dynamics has been moderately used in some medical applications. For instance, one of the key applications of fluid mechanics is in the field of cardiovascular disease research, where it has been used to study blood flow in the human circulatory system. This is critical in understanding the mechanisms underlying various cardiovascular diseases, such as hypertension and atherosclerosis (Hunter & Feinstein, 2019). In addition, fluid mechanics has also been used in respiratory research to study the flow of air in the lungs, which is important in understanding and treating conditions such as asthma and chronic obstructive pulmonary disease (Glotberg, 2012). Moreover, fluid mechanics has been used in drug delivery systems, where it is applied to optimize the design of drug delivery devices to ensure efficient and controlled drug delivery. The application of fluid mechanics in drug delivery systems has resulted in the development of numerous innovative devices, such as micro- and nanofluidic devices, which have revolutionized the field of drug delivery (Layle et al., 2018).

Another valuable medical application of fluid dynamics includes cancer treatment. After a century of rapid advances in theory, numerical methods, hardware, and software, the fluid dynamics community has recently developed a powerful set of imaging, analysis, and simulation tools that are perfectly suited for the investigation of transport processes in cancer. Generally, fluid dynamics has been applied in cancer research to study the behavior of cancer cells and the surrounding tissues and fluids. Researchers use various techniques to analyze the fluid dynamics of tumors, such as computational fluid dynamics and magnetic resonance imaging (Jarral et al., 2020). By studying blood flow patterns in and around tumors, researchers can gain insight into the mechanisms of tumor growth, metastasis, and response to therapy. Fluid dynamics models can also be used to study the behavior of cancer cells in fluids such as blood and lymphatic systems, to develop strategies to prevent or slow down the spread of cancer (Follain et al, 2020). Additionally, fluid dynamics is potentially useful to optimize drug delivery systems for cancer treatment (Kashkooli et al., 2020). The behavior of fluids in the body affects the delivery of drugs to the tumor site, and researchers use fluid dynamics models to design drug delivery systems that can optimize drug delivery and improve the effectiveness of cancer treatment.

To sum up, the application of fluid dynamics in cancer research can provide a deeper understanding to the development of new strategies for cancer diagnosis, treatment, and prevention. However, there is a relatively limited number of pioneering studies that relate cancer to fluid mechanics properties. This paper presents the most important and recent developments of cancer fluid dynamics-based research.

Cancer: A Global Health Challenge

Every year, cancer claims millions of lives globally and is considered a prevalent cause of death. It is estimated that there are 19.3 million new cases of cancer each year, with the number of deaths reaching 10 million in 2020 alone. (American Cancer Society, 2021). The most common types of cancer are breast, lung, prostate, and colorectal cancers. While cancer can affect people of all ages, the risk of developing cancer increases with age. It is estimated that approximately 39.5% of men and women will be diagnosed with cancer at some point during their lifetime. However, survival rates for cancer have been improving, with the 5-year relative survival rate for all cancers combined increasing from 49% in the mid-1970s to 70% in recent years (Dafni et al., 2019). This is due in part to advances in cancer treatment and early detection.

I. Exploring the Spectrum of Cancer Treatments

The most important and commonly used treatments for different types of cancer include surgery, immunotherapy, hormone therapy, targeted therapy, radiation therapy, and chemotherapy. Surgical intervention involves the removal of cancer along with some healthy tissue that is attached to it. While this approach can be effective for small tumors or localized cancer, it cannot eliminate all cancer tissues that have spread. Examples of surgical procedures include mastectomy for breast cancer or prostatectomy for prostate cancer (Kaidar et al., 2021; Cacciamani et al., 2021). In addition, Immunotherapy, also known as biological therapy, enhances the immune system to fight cancer. This is achieved by using antibodies that block protein functions and bind to cancer cells, training the immune system to recognize, attack, and possibly eliminate the tumor. Moreover, hormone therapy is another treatment that alters hormone levels based on the type and risks of cancer, which can reduce the rate of growth (Kuhle et al., 2016). It is most effective against breast, reproductive system, and prostate cancers, but its side effects vary depending on the drug used, age, sex, and type of cancer. Also, targeted therapy focuses on cancer cells that allow them to divide, grow, and spread, by using specific proteins that target certain domains of cancer cells (Sanna et al., 2014). These proteins control the tumor, inhibiting, overexpressing, or mutating the cancer cells, allowing for complete virus control. Constant updates and improvements are being made to this method for better outcomes, and one of these improvements lies in applying fluid mechanics principles in cancer treatments like chemotherapy. Radiation therapy employs high-powered energy beams such as x-rays or photons to eliminate cancer cells. It is typically used in combination with surgery to reduce the size of cancer. Lastly, Radiation therapy can be delivered externally or internally through brachytherapy, which involves placing radioactive wires or seeds near the tumor. Finally, chemotherapy is a widely used treatment involving drugs to kill cancer cells by slowing or stopping their growth, thereby preventing them from dividing rapidly. It can either cure cancer or reduce the likelihood of it recurring (Chabner et al., 2005).

Fluid Mechanics in Chemotherapy: Improving Drug Delivery for Better Results

As previously mentioned, chemotherapy is a commonly used treatment option for cancer, but its effectiveness is often limited by the complex physiological barriers that must be overcome to deliver drugs to the tumor site, so fluid mechanics has been applied in various ways to overcome these barriers and improve the effectiveness of chemotherapy cancer treatment.

One application of fluid mechanics in chemotherapy cancer treatment is the use of microfluidics (Zhang et al., 2013; Boussommier-Calleja et al., 2016). Microfluidics involves the manipulation of small amounts of fluid in channels or chambers that are only a few micrometers in size. This technology has been used to create devices that can mimic the microenvironment of tumors, allowing researchers to test how drugs interact with the tumor microenvironment. For example, researchers have used microfluidics to study how the structure and composition of the extracellular matrix in tumors affect the diffusion and distribution of drugs (2016).

Another application of fluid mechanics in chemotherapy cancer treatment is the use of fluid dynamics simulations. Fluid dynamics simulations involve using mathematical models to simulate the flow of fluids in complex environments, such as blood vessels or tumors. These simulations can be used to optimize drug delivery by predicting the movement of drugs in the body and identifying areas of low drug concentration. For example, researchers have used fluid dynamics simulations to design drug delivery systems that use magnetic fields to guide drug particles to the tumor site (Luan et al., 2018).

In addition to these applications, fluid mechanics has also been employed to study the effects of physical forces on tumor cells. One such force is fluid shear stress, which is the frictional force exerted by fluid flow on the surface of cells. Researchers have found that fluid shear stress can affect the behavior of tumor cells by promoting cell migration and invasion (Han et al., 2020). This information can be used to design drug delivery systems that target specific areas of the tumor microenvironment, such as regions with high fluid shear stress, to improve drug efficacy.

II. Reflecting on Progress and Looking Towards the Future

In conclusion, the application of fluid mechanics in chemotherapy cancer treatment has shown promise in improving drug efficacy and overcoming physiological barriers to drug delivery. However, there is still much research to be done to fully understand the complex interactions between fluids, drugs, and tumors. With continued advancements in microfluidics, fluid dynamics simulations, and other fluid mechanics technologies, researchers will be better equipped to develop more effective cancer treatments.

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