Nanotechnology and Machine Learning in Cancer Detection and Treatment

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Abstract

While relatively new fields, nanotechnology and nanoscience offer new, potential avenues in which science is conducted and performed. In this paper, our focus will be the current nanotechnology in development and its current impact upon cancer detection. We will also examine how machine learning can be applied to cancer analysis, and how machine learning can indirectly impact cancer research. In addition, the paper will identify the potential combination of the two fields to advance cancer detection and treatment, as well as current limitations of both fields in cancer research.

Introduction

Nanotechnology refers to the application of materials, devices, or systems at the nanoscale. It involves observation, research, manipulation, and production of materials at the nanoscale (between 1-100 nanometers) [1]. It is a science that can be applied to various fields including chemistry, biology, and engineering. While nanotechnology and nanoscience are relatively new areas of study, their potential applications in the medical field offer novel ways for the diagnosis and treatment of various diseases, in addition to providing new avenues to conduct research in the sciences. By manipulating materials at the molecular level, scientists can approach research in a myriad of ways, creating novel solutions to problems that would otherwise be impossible with current technology.

While nanotechnology is yet to be commonplace in the sciences, it is becoming more prevalent as research continues into its potential applications. One such application is within the field of medicine, where nanotechnology is being applied to cancer research.

According to the CDC, Cancer is the second leading cause of death within the United States [2]. While certain cancers can be found early through screening tests, there can be several delays in diagnosing cancer which can impact the course of treatment and chances of curing certain cancers [3]. Early screening for cancers is critical in improving chances of survival for certain types of cancers [4]. Nanotechnology can play an important role within early cancer detection and diagnosis. Researchers have developed various types of nanotechnology that have been designed to target certain components of cancer such as cells and metastasis. These developments, as will be discussed with this paper, can subsequently impact the ability of scientists and healthcare professionals to screen, detect, and treat various cancers.

In addition, machine learning is another field of study which can have several applications in cancer research. Machine learning techniques are becoming increasingly popular amongst medical researchers due to the ability to identify patterns and relationships within complex datasets, providing prognosis and predictions regarding cancers [5]. DNA analysis can be done utilizing machine learning, which can be expanded upon in cancer research.

Nanotechnology

One such example of nanotechnology development was conducted by a research team at the University of California, Los Angeles (UCLA). While research has been done into materials that replicate natural cellular environment and behavior, the UCLA research team focused on the development of "NanoVelcro" cell-affinity substrates which were designed for detection, isolation, purification, and analysis of circulating tumor cells (CTCs) with high efficiency. Different iterations of the NanoVelcro were developed by the research team, each designed for specific clinical and research purposes, ranging from enumeration to capture of CTCs. By doing so, CTCs could be characterized and analyzed with more efficiency than currently available methods [6].

DNA computing is another form of nanotechnology which involves the construction of DNA molecules to create molecular structures. In one such study, DNA origami, a method used to create precise DNA nanostructures in size and shape, was used to create nanorobots that target cancer cells directly. The goal of the study was to precisely deliver thrombin to cancer cells, effectively cutting off its blood supply and stunting tumor growth. This was accomplished by creating a hollow-shaped tube which loaded thrombin along the internal sides. Fastener strands containing DNA aptamers were used to close the nanorobot at the seams. The DNA aptamers, upon recognizing the nucleolin on the surface of circulating tumor cells, would induce a transformation in the structure of the nanorobot to expose and release the thrombin [7].

The results of this study demonstrated that the nanorobots were able to effectively induce thrombosis in blood vessels associated with tumor growth. In addition, the nanorobots were shown to have been successfully degraded by phagocytosis in the liver of the test subjects, with no significant changes in blood coagulation or toxicity in blood levels [7]. The study provides proof of concept that precisely targeting tumor cells is possible using nanostructures while maintaining the safety of the surrounding area within the body.

Other applications of nanotechnology have been used in cancer research, with the intent of improving upon the current methods of early detection and diagnosis of cancer. Cancer imaging is one such area where nanotechnology is being researched and applied. Using specially designed quantum dots with near-infrared spectrum fluorescence has improved the use of visible spectral imaging in screening for certain cancers such as liver and pancreatic cancer [8]. In cancer biomarker screening, biomarkers from blood, urine, and saliva are examined to screen for cancer. Several biomarkers associated with many cancers have been identified with current research. However, current profiling tests can often remove biomarkers of interest which subsequently affects the cancer screening. Using nanoparticles, studies have derived a method of capturing and enhancing these biomarkers, which provides a more accurate cancer screening [8].

Machine Learning

Machine learning is a branch of artificial intelligence which involves learning from datasets. Based upon the provided data, the designed model can either map input to output in supervised learning, or identify patterns and produce predictions based upon the data in unsupervised learning. Using existing data on certain types of cancers, machine learning has been utilized in research to predict cancer recurrence through various algorithms and models [5]. In addition to predictive models, machine learning can be utilized in the classification of cancers.

Gene expression provides valuable information regarding a patient's disease state. mRNA can reveal whether a particular gene is active or inactive, which can play a role in identifying certain types of cancers. Through the use of microarray data, researchers are able to classify different types of tumors with more precision [9]. By using feature-specific algorithms to reduce high-dimensional data to reduce the complexity, the microarray data can be analyzed more precisely. Researchers have done parallel genomic screening, searching for potential biomarkers, genetic relationships, and mutations that can indicate the presence of disease. Examining data sets using machine learning can identify hidden patterns that can be later used for drug development used to treat cancers [9].

Much of the research into machine learning in the study of cancer has been primarily focused upon genetic analysis, classification, and ways to improve the early diagnosis of cancer. In conjunction with algorithms and learning models, there are other ways in which machine learning can be used. These methods, while not directly involved in cancer research, can still be applied to the field.

For example, the design of materials involves predicting properties and synthesizing complex systems, then deriving potential solutions for chemical-synthesis based on varying factors such as cost and toxicity of material [10]. Because there is a plethora of solutions that can be examined, using prediction modeling from machine learning can better predict synthesis routes for study [10]. At the nanoscale, synthesis of materials becomes even more complex, due to the change in properties of materials as materials are reduced in size. To address this challenge, machine learning can be used to predict the properties of nanomaterials, as well as optimize potential structures [11].

Conclusion

Based upon the provided examples, it is evident that nanotechnology and machine learning play a significant role in the progression of cancer research. Both fields provide novel ways of how to better classify cancers, target tumor cells, and find new relationships on the genetic level that can provide more precise results in diagnosis and treatment. In addition, the applications of machine learning and nanotechnology can be used in other fields which could ultimately contribute to cancer research.

While both nanotechnology and machine learning have been studied before, both fields have yet to become commonplace within the study of cancer. There are limitations to the hardware produced at the nanoscale, as much of the nanotechnology still relies heavily upon the use of biological substrates to initiate interactions with the cancer cells. In addition, many of the machine learning models require a large amount of computing power to sort through the large and complex data acquired from genetic tests. Formulation of such algorithms designed to specifically target cancer also require substantial amounts of data to run, which ultimately affects how machine learning can be used given the current state of cancer research.

However, there is a large potential of growth in both fields which can ultimately change the way research is done in the sciences. Using machine learning for the discovery of new materials can pave the path for the advancement of nanoscience. Subsequently, the development of new hardware capable of supporting machine learning and computationally intensive tasks at the nanoscale can open new avenues for improvement in the diagnosis and treatment of not only cancer, but other disease states as well. The possibility remains that the two fields can eventually integrate with one another seamlessly, producing new technologies available at a mass scale that can be applied beyond the field of medicine.

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