INTRODUCTION: CANCER IS A GLOBAL HEALTH PRIORITY

According to the American Cancer Society, cancer is “a group of diseases characterized by the uncontrolled growth and spread of abnormal cells” [1]. If the spread of these cells is not controlled, it can lead to death. In 2008, there were approximately 7.6 million deaths due to cancer in the world—and two-thirds of them occurred in low- or middle-income countries [2]. Additionally, statistics show that “cancer kills more people worldwide than HIV/AIDS, tuberculosis, and malaria combined,” making it a global health priority [2].

For a variety of cancers, a patient’s likelihood of survival is closely related to the income of his or her country [2]. Low-income countries tend to trail behind wealthier ones in cancer survival rates due to their lack of awareness and inability to detect or prevent the disease in its early stages [2]. These countries also have difficulties accessing the newer, more effective chemotherapeutic treatments that have been developed and made available to those in first world countries.

However, these treatments have many flaws, making them far from ideal for patients. For example, chemotherapy is frequently said to have low efficacy, due to the development of undesirable side effects such as vomiting, nerve killing and neutropenia, a condition that leads to increased susceptibility to infection [3]. Also, traditional chemotherapeutic drugs “prevent cell division, trigger cell death, and/or reduce blood vessel growth,” making them very effective in the killing of cancer cells, but fatal overall, as the drugs fail to discriminate between normal and cancerous cells [3].

To combat chemotherapy’s cost and efficacy issues, “the potential of novel therapeutics needs to be exploited” [3]. One of these therapeutics is nanotechnology, an innovative, multidisciplinary field, that allows for effective, targeted and personalized solutions for the treatment of cancers by combining the realms of chemistry, physics, engineering and biomedicine [3]. Some of the first FDA-approved uses of nanotechnology in medicine were for cancer treatment [4]. Its potential is so promising that the National Cancer Institute (NCI) developed the Alliance for Nanotechnology in Cancer in 2004 to promote the research and development of the field [4].

WHAT IS NANOTECHNOLOGY?

Nanotechnology “involves the manipulation of properties and structures at the nanoscale” [3]. Several kinds of nanotechnologies are used in the medical world, such as nanoparticles and dendrimers [5]. Nanoparticles are usually made from a variety of inorganic materials such as metals, semiconductors, or oxides and tend to have dimensions smaller than 1,000 nanometers [5]. These particles can be created “to contain therapeutic molecules that they release when they bind to their target” [5]. To increase their effectiveness, dendrimers are used in conjunction with the particles. These ordered, branched polymers can be designed to have a different medicine or component in each branch, allowing a single nanoparticle to have multiple functions [5]. These nanomaterials can be used for a range of applications in the diagnosis and treatment of disease, and such applications are known as “nanomedicine” [4].

Nanomedicine’s promise can be summarized by the word “control” [5]. Currently, when drugs are given to patients, control over the drugs is lost, and the medication is free to roam the body, effectively treating the target area, but also possibly destroying healthy cells or organs. With nanomedicine, doctors are able to retain that control. Theoretically, they “can program [a] particular nanomaterial to do what [they] want it to do” [5].

In addition to adding control, nanomedical systems allow for improved solubility of water-insoluble drugs (decreasing toxic side effects) and minimized drug degradation [3]. These systems could also reduce the frequency of dosages, consequently improving patient compliance to treatment regimens [3].

TREATING CANCER WITH NANOMEDICINE

Nanomedicine has the potential to be transformative in the diagnosis and treatment of cancer. To diagnose cancer, physicians rely on imaging that reveals tumors and molecular tests that can identify genes or proteins that are present at abnormal levels [5]. Dr. Anna Barker, former deputy director of the National Cancer Institute, revealed that nanomedicine allows for “unprecedented levels of
sensitivity,” with technologies able to detect as little as one molecule of interest in a drop of blood [5]. Nanomedicine can also improve diagnostic imaging by enhancing the contrast of the imaging through magneto-fluorescent nanoparticles. These particles have a magnetic and crystalline nature that heightens their ability to be detected, and are internalized, not metabolized, by cells so they are retained and can be used before and during surgery for tumor detection [5].

Nanomedicine can improve cancer treatment by improving its targeting precision [5]. Having more specific targeting to tumor cells limits the damage done to healthy cells, meaning cancer therapy’s adverse side effects could be lessened. Such selectivity can be “achieved by drugs encased in nanoparticles that do not release their contents until they penetrate tumor cells” [5]. Selectivity can also be attained through “active targeting,” which is accomplished by the nanomaterials being “decorated with antibodies or other compounds that cause them to selectively bind to tumor cells” [5].

INHALED CANCER THERAPY

The current goal of scientists, oncologists, and biomedical and chemical engineers is to integrate nanotechnology with the inhalational route of drug administration [6]. Such integration has been encouraged because the lungs are an ideal entrance for drugs to the bloodstream due to their large surface area and thin absorption membrane [6]. Also, drugs that are inhaled are less likely to regress in concentration before reaching circulation through the bloodstream [6]. Furthermore, the inhalational delivery of cancer drugs could reform lung cancer care. This is crucial as lung cancer kills 1.5 million people worldwide per year—more than the number of people who die from breast, colon, pancreatic and prostate cancer combined [7]. This astounding number of deaths is due, in part, to the fact that many patients are not diagnosed until they are in advanced stages of the disease, which are more difficult to treat. According to Tamara Minko, chair of the Department of Pharmaceutics at Rutgers University, was able to improve the efficacy of lung cancer treatment with the help of graduate students. This was achieved by using a combination of nanoparticles of cancer drugs and small interfering molecules that shut down the ability of the cancer cells to resist attack [7]. In the most recent animal study, the lung tumors of mice treated with inhalation therapy virtually disappeared [7].

The next step in inhalation therapy for lung cancer would be to conduct clinical trials to determine whether the same positive effects could occur in humans, as current lung cancer patients suffer the severe side effects of traditional chemotherapy. Despite being a relatively new concept, there are a few clinically successful nanoparticle inhalant systems, such as dry powder inhalers ( DPIs), which work similarly to inhalers for asthma patients [7].

Dry powder inhalers are devices that deliver medication into the lungs in the form of dry powder when deep, fast breaths are taken through the inhaler. They are propellant-free, portable, user-friendly, and have improved stability over liquid aerosols [8]. DPIs are most commonly used to treat diseases such as asthma and bronchitis, but are currently being innovated for cancer treatment.

Dry powder formulations are usually prepared by mixing nanoparticles of a drug with larger carrier particles that improve dosing accuracy [9]. The nanoparticles allow for uniform distribution of drugs among the alveoli (sacs of the lung that allow oxygen, and in this case, medication to move between the lungs and the bloodstream) [9].

Research on the inhalers reveals that the powdered formulations are more cytotoxic against lung cancer cells as compared to a free drug [10]. The administration of anticancer drug, TAS-103, loaded nanoparticles via inhalation “demonstrated higher retention of drugs in the lung (approximately 13-times higher) compared to those delivered via intravenous injection” [10]. These inhaled nanoparticles also significantly reduced masses of metastatic lung tumors while exerting negligible toxicity to healthy cells [10].

CONCLUSION: NANOMEDICINE IS A FEASIBLE SOLUTION

By combining the fields of nanomedicine and inhalation therapy, cancer treatment can be totally reformed. Inventions like the dry powder inhaler are innovative, yet affordable, so they can help patients in all areas of the world. Also, the inhalational route of drug delivery increases efficiency while decreasing systemic toxicity, overcoming the two “critical barriers” advanced lung cancer therapy faces [7].
Continued advancements in the realm of nanotechnology means the cancer pandemic can be stopped. I have always been passionate about helping others, and by becoming an engineer and working to improve cancer care, I can help millions of others. The idea of being able to positively impact not just another person, but the world, is exciting and surreal to me. To do something as big as work to fight cancer is even more exciting, as cancer affects the entire world in such a detrimental way. With the impacts already made on the medical field by nanomedicine, it is clear that the technology has the potential to revolutionize cancer care, meaning researching nanotechnology should be a top priority for experts.

**SOURCES**


**ADDITIONAL SOURCES**


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