International Journal of Science and Research Archive
eISSN: 2582-8185
Cross Ref DOI: 10.30574/ijsra
Journal homepage: https://ijsra.net/

(REVIEW ARTICLE)

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The usage of nanotechnology in the detection and treatment of cancer

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International Journal of Science and Research Archive, 2025, 15(02), 1157-1166

Publication history: Received on 04 April 2025; revised on 20 May 2025; accepted on 22 May 2025

Article DOI: https://doi.org/10.30574/ijsra.2025.15.2.1526

Abstract

Cancer remains a critical health challenge on a global level. Existing diagnostic and treatment methods have serious limitations which contribute to rising incidence and mortality, this study explores the usage of nanotechnology to overcome these limitations by enabling earlier tumor detection and making treatments more precisely targeted. Conventional imaging techniques often fail to spot tumors in early stages or differentiate benign growths from malignant ones, while also typically relying on ionizing radiation, which can damage healthy tissues. Similarly, standard cancer therapies often cause severe side effects due to the lack of specificity and inability of eliminating tumors without harming normal cells. This study examines the usage of emerging nanotechnology-enabled tools, including silicon nanowire biosensors, which exhibit exceptionally high sensitivity and could allow for tumor detection at much earlier stages. Beyond diagnostics, nanotechnology can also enhance therapy: nanocarrier systems (for example, liposomes) can deliver anticancer drugs directly to tumor sites, thereby reducing exposure of healthy tissues. Similarly, stimuli-responsive systems such as ultrasound-triggered drug release could further improve treatment precision and effectiveness. However, like any emerging approach, challenges remain: sensor devices may suffer from background noise, some nanomaterials could pose toxicity risks, and high development costs currently limit widespread adoption. This work is based on an extensive review of peer-reviewed literature and expert consultation, aimed at evaluating the feasibility and potential impact of nanotechnology in oncology. The findings suggest that nanotechnology holds significant promise for cancer care. At the same time, the results underscore the need for continued research to overcome existing limitations.

Keywords: Nanotechnology; Cancer Detection; Targeted Drug Delivery; Silicon Nanowires; Liposomes

1. Introduction

For over a hundred years, cancer has been known to be one of the most prominent and lethal diseases in the world. Even with all the technological advancements that have occurred over the past century, there are still not many effective detection and treatment methods. In fact, in 2018 alone, the deaths of 9 million people were attributed to cancer [1]. According to a study conducted by the International Agency for Research on Cancer, the severity of this degenerative disease is not expected to decrease, as the number of new cancer cases per year is expected to rise to 29.5 million by the year 2040, with more than half (16.4 million) leading to death [2]. As a result, cancer is expected to remain one of the life-threatening, yet incurable diseases worldwide.

The human body's cell cycle involves the continuous death of damaged cells and their replacement with new and healthy cells through cell division. However, errors may occur during cell division, which would lead to cancer development as it would cause a change in DNA, also known as a mutation. Mutations may also be a consequence of environmental factors such as exposure to radiation, which leads to disturbances in systems of the body such as the cell cycle and

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consequently leading to the failure of programmed cell death. In the case where the damaged cells do not die, they instead grow unmanageably until they become tumors. These can be cancerous tumors that can spread throughout the body and destroy healthy tissues.

Unlike other deadly diseases such as respiratory illnesses, cancer could occur almost anywhere in the body, as each type of cancer affects a different area. For instance, carcinoma is the most common type of cancer, and it begins in the skin, lungs, and other organs. On the other hand, leukaemia originates in the blood, whereas sarcomas appear in the bones and tissues. The significant differences between each type of cancer lead to a consequential difference in symptoms of each type. This makes it especially difficult for those who develop the disease to recognize the symptoms, hence leading to a late diagnosis. Currently, detection of the tumors is done through imaging tests; however, the tests are limited as the precision of detecting small tumors is low, therefore the tests fail to detect cancer in its early stages. Hence, considering the aforementioned factors, it is evident that the early detection of cancer still presents a major challenge in the medical field. Moreover, conventional imaging tests possess other drawbacks such as the inability to differentiate between the types of tumors detected, and in some cases, the tests themselves could also cause a mutation, which would lead to cancer [3]. These issues hinder the ability to effectively and quickly detect cancerous tumors, hence resulting in the continuous spread of cancer throughout the body. Consequently, the patient's condition worsens, which would lead to a more difficult treatment procedure.

Currently, there are no universal cancer treatment methods as the suitability of each method depends on the type and stage of cancer. Conventional methods include chemotherapy, radiation therapy, and targeted therapy, all of which can also be used in combination with one another. However, there are several problems associated with these methods of treatment. These problems stem from both the aspect of expected side effects such as fatigue and hair loss, as well as unexpected side effects such as damage to nearby healthy cells due to the inability to specifically target cancer cells and consequently the formation of a new cancer in another area of the body [G.Husseini, personal communication, June 28, 2021]. In addition, current cancer treatment methods may fail to eliminate all cancer cells. Hence, it is clear that the conventional cancer treatment methods are far from ideal due to the frequency and severity of the side effects associated with them.

An improvement to the current detection and treatment methods could be through the utilization of nanotechnology. The probability of early detection could significantly increase by utilizing nanotechnology. For instance, nanoparticles may be used as contrast agents. The benefit of contrast agents is their enhancement of the visibility of tumors when viewing imaging tests by having a significant contrast in color between healthy and cancerous cells. The contrast makes identification easier and therefore allows for much earlier detection [4]. Furthermore, nanotechnology can be used for newer detection methods, such as placing silicon nanowire sensors in the body, making detection easier and more efficient by detecting the specific molecules related to cancerous tumors [5]. This allows for precise identification of the tumor's location and hence an easy detection as the information is transmitted to a computer where it can be easily read.

Furthermore, the benefits of nanotechnology can also be utilized in the treatment of cancer. The small size of nanoparticles allows for the usage of nanotechnology to solve the lack of targeted drug delivery, which is a serious problem with conventional cancer treatment methods. The implementation of successful targeted drug delivery would significantly decrease the chances of harming surrounding healthy tissues. This solution may be implemented using nanomaterials that are programmed to release anticancer drugs depending on specific triggers, which indicate they have reached the tumor site. Hence, the impact on healthy tissues will be minimized while the effectiveness of the drug is simultaneously maximized. Therefore, in addition to nanotechnology's benefit to the detection of cancer, its usage in the treatment of cancer may also prove to be a promising solution.

2. Identification and discussion of problems

The problems with conventional methods in the detection and treatment of cancer demand novel solutions which are more reliable. The problems in the detection of cancer include the inability to detect cancer cells at an early stage while the issue with treatment is the lack of targeted delivery of drugs to the cancer cells. With the current advancements in nanotechnology, it is a promising solution to the current problems which poses the question of: how can nanotechnology be used in the detection and treatment of cancer?

2.1. Drawbacks of Conventional Imaging Tests

A crucial part of treating any disease effectively is early detection, which is confirmed by a study conducted on 209 cancer cases, in which it was concluded that early diagnosis results in more successful treatment outcomes [6].

According to Dr. Ghaleb, the diagnosis of cancer often begins with the patient's ability to recognize the symptoms they are experiencing and acknowledge the need to visit a physician. Although, the main problem is that even if people were vigilant and tests were performed on the patient early on, Dr. Ghaleb stresses that imaging tests such as Magnetic Resonance Imagining (MRI), Computerized Tomography (CT), and Positron Emission Tomography (PET) have significant limitations. These conventional imaging tests are only capable of detecting a tumor once it develops into a size which is large enough, this would occur in the later stages of cancer, once the cancerous cells have metastasized [G.Husseini, personal communication, June 28, 2021]. However, the disease becomes more aggressive with time, so when the tumor eventually grows and can be detected by the imaging tests, the cancer would have significantly developed, and the patient's condition would have worsened. Consequently, the patient's probability of a successful treatment would decrease.

Conventional imaging tests possess additional drawbacks which deem them ineffective, such as the high chance of detecting nodules. Although conventional imaging tests are able to detect tumors, it is difficult to differentiate between benign and malignant tumors, hence requiring a biopsy to confirm. Consequently, the patient would have to undergo invasive surgery to determine whether or not the tumor is cancerous. Table 1 shows that a considerable amount of invasive surgeries are performed due to the detection of benign tumors [3].

Furthermore, the limitations of imaging tests not only make them ineffective but may even make them harmful due to the way the tests work. In the case of a CT, a combination of X-ray scans is taken of the body from different angles. These scans are then used to create an image of the tissues and bones in a certain area of the body to detect any tumors. Utilizing a combination of images from different angles allows a CT scan to provide more information than a plain X-ray. However, it also leads to high exposure to electromagnetic waves which could lead to mutations [3]. As for PET scans, a radioactive drug referred to as a radiotracer is injected into the patient and is then absorbed by both healthy and diseased cells in the body. Although the radiotracer is absorbed by all cells, a greater amount is absorbed by the diseased cells which allows for the detection of cancerous cells through the utilization of a scan to detect the radiotracer [7]. Even though the risk of a mutation due to a PET scan is lower than a CT scan due to the radiotracer not remaining in the body for a long time, the absorption of the radiotracer by healthy cells would subject the body to radiation, which similarly to a CT scan, would lead to mutation. Therefore, patients who require follow-up imaging tests are at risk of developing cancer from the tests themselves.

Table 1 Benign tumor detection cases which resulted in a biopsy [3]

Study	**n (%)**
Japan (Tokyo)	27 of 49 (55)
Japan (Nagano)	9 of 43 (21)
USA (Rochester, MN)	8 of 40 (20)
Germany (Munster)	3 of 13 (23)
Italy (Milan)	6 of 28 (21)

2.2. Conventional Treatment Method

Currently, one of the main conventional methods used to treat different types of cancer is chemotherapy. Although it can be successful, it has severe shortcomings; it poses a high level of threat and toxicity to surrounding healthy tissues. This leads to major side effects such as low immunity, low blood count, heart failure, loss of hair, etc. [G.Husseini, personal communication, June 28, 2021]. The main reason that all the side effects occur is that the drugs administered fail to target the affected site and instead also travel to healthy tissues that do not need it. After a patient goes through a sufficient number of chemotherapy cycles they are declared in remission, meaning that their symptoms have completely disappeared [G.Husseini, personal communication, June 28, 2021]. However, in many cases, patients may relapse causing cancer to recur more aggressively. This aggravated reaction occurs as the cancer cells become smarter and develop a mechanism where they become resistant to chemotherapy. The problem is that the recurring cancer cells are not only resistant to the drug administered before, but different anticancer drugs as well, hence developing multi-drug resistance (MDR) [G.Husseini, personal communication, June 28, 2021]. MDR occurs because the cell membranes possess P-glycoprotein (P-gp) pumps, which are proteins that typically transport toxins out of cells. However, in the case of MDR, while transporting toxins out of the cells, the P-gp pumps also attach themselves to anticancer drugs inside the cells, pumping them out of the tumor cell whenever they enter [8]. Consequently, the drugs do not reach the nucleus and the tumor cells do not die, instead they further metastasize, leading to the death of the patient. Furthermore, for

the administered drugs to be effective, the cell must contain the specific cellular component that is going to be targeted, such as the DNA. However, due to MDR, even if the cell contains this target, there is no guarantee that the drugs will eliminate all the cancer cells [9]. This leads to a decrease in the immersion of drugs into the cancer cells and thereby a decrease in their effectiveness. Higher doses of anticancer drugs would then be required, which may not be feasible due to their severe side effects. This is a significant problem in cancer treatment because the anticancer drugs are deemed ineffective. Therefore, current conventional treatment methods such as chemotherapy inflict significant harm to the human body due to their lack of targeted delivery.

3. Solutions and findings

3.1. Replacing Conventional Imaging Tests with Nano-biosensors

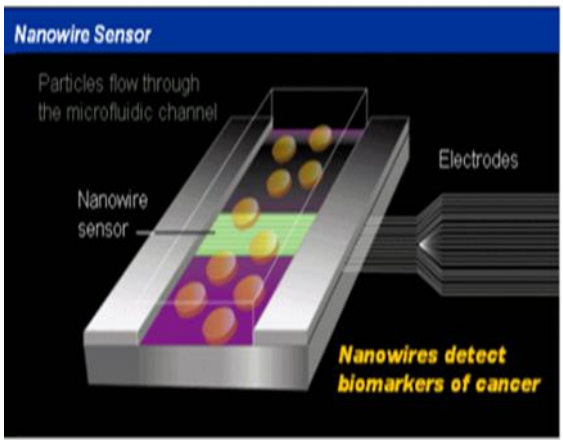

Figure 1 Nanowire Sensor

Nanotechnology can be utilized to tackle the problems with conventional methods of detection. In the case of early detection of small tumors, nanotechnological devices such as nanowire biosensors will be used. The specific nanowire used in the biosensor would be silicon nanowires (SiNW) since silicon is a semiconductor, it possesses the properties of both a conductor and an insulator. These properties would allow the SiNW to act as a bioreceptor, which along with a transducer and a signal processor make up the three main sections of a biosensor. The bioreceptor binds to the cancer cells, which are referred to as the analyte; the transducer then converts the binding of the analyte into a detectable signal. This allows the signal processor to convert the detected signal into information which is then used to determine the extent to which cancer has spread. Additionally, the large surface area of SiNW allows them to easily interact with cancer antigens, which are substances produced by the tumors, hence allowing the SiNW to detect small tumors early on. Hence the usage of silicon nanowires would allow for the fast delivery of information from the signal processor about the tumor's location [5].

The SiNW is positioned in a microfluidic channel within a field-effect transistor (FET), which is a nanowire sensor that acts as a transducer, as shown in Fig. 1 [10]. The SiNW in the FET are doped with positive and negative electrolyte ions to allow for a change in their conductivity as the conductivity depends on the charge of the bound cells. Cancer cells are always negatively charged, while the healthy cells are either neutral or slightly positively charged [11]. Hence, when a cell is bound to the surface of SiNW, if it is positively charged, the conductivity of the nanowires will decrease, indicating that it is a healthy cell; if the cell is negatively charged, it will cause an increase in the conductance of the SiNW, indicating that it is a cancerous cell, as shown in Fig. 2 [6]. Due to the change in conductance that occurs upon the interaction between the SiNW and the analyte, the FET then converts the binding into sensed signals [5], [6].

Accordingly, the nanowires will detect the presence of the transformed genes associated with cancer, which would help identify the precise site of the cancer cells. The recorded data will then be transmitted to a computer through the FET. Furthermore, due to the SiNW's capabilities of detecting malignant tumors, there will be no need for a biopsy to determine the type of the tumor. Consequently, performing invasive surgeries would no longer be required. Furthermore, SiNW does not expose healthy cells to radiation, thereby solving the problem of imaging tests causing mutations that could lead to cancer. Therefore, the usage of nanotechnology in detection would eliminate the need for conventional imaging tests such as CT and PET scans.

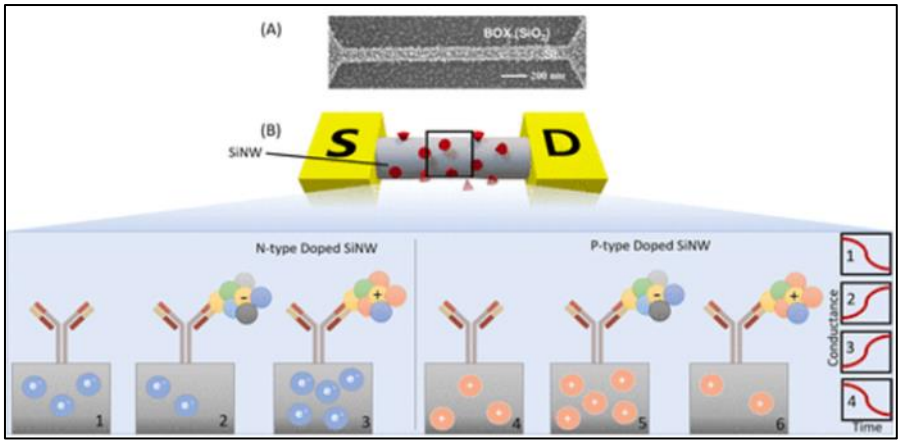

Figure 2 Process of detecting cells using SiNW in FET.

3.2. Targeted Delivery Using Nanotechnology and Ultrasound

To minimize MDR and the damage done to the surrounding healthy tissues, nanotechnology-based treatment employs site-specific delivery using nanomaterials (NMs), which are tiny particles, such as liposomes. Liposomes are made up of cell membrane components such as lipids and cholesterol. Cholesterol is highly insoluble in blood and water, making liposomes perfect for drug delivery as they would be less absorbent of water, meaning the chances of water entering the nanocarrier and solvating the drug decrease tremendously [12]. Since liposomes have the same structure as cell membranes, they are able to effectively deliver the anticancer drugs through an improved lipid-lipid interchange process, accelerating the deposition of the drug into the tumor cells [13]. Furthermore, the small-sized nature and the wideness of the NMs enhance their ability to be absorbed by the targeted cells, their bioaccumulation at the tumor site, and their efficiency in passing through the blood-brain barrier. These properties of NMs facilitate the delivery of the drugs to a specific site in a controlled manner [13], [14].

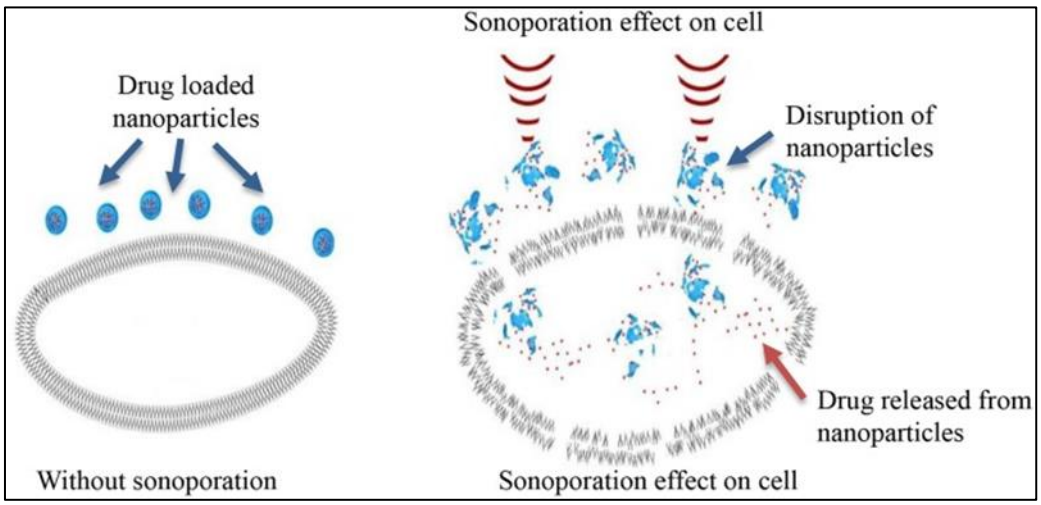

Figure 3 Sonoporation effect on cell membrane in drug delivery

However, for the successful delivery of the drugs to the tumor cells, the NMs require a targeting technique. There are several targeting techniques currently being used, one of which is ultrasound. Treating the cancerous area with ultrasound results in twice as much accumulation of the NMs on the tumor sites due to the energy from the ultrasound rays. The energy stimulates several biophysical effects in the tumor cells, such as cavitation and sonoporation. Cavitation occurs when ultrasound radiations lead to the formation, growth, oscillation, and degeneration of small gaseous bubbles. Upon the interaction of the tiny bubbles with ultrasound rays, they absorb the ultrasonic energy, which leads them to vibrate at a high rate and broaden forcefully [15], [16]. This absorption of energy leads to a jolt of fluid rising and pushing against the cell membranes, causing them to experience a change in their arrangements. This process, known as sonoporation, results in the formation of small pores through which the NMs enter the tumour cell and release the drugs as shown in Fig. 3 [16].

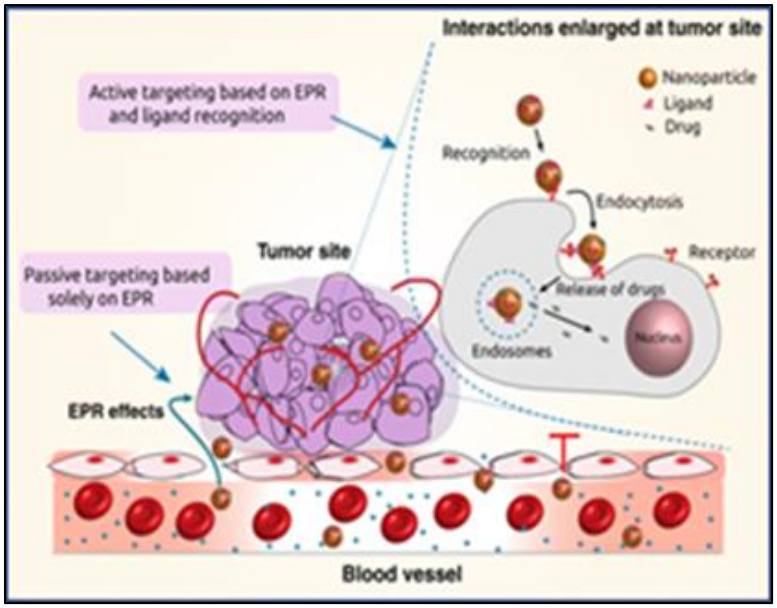

Figure 4 EPR Effect in Targeting Tumor Cells

During sonoporation, the drugs are attached to the NM's surface; guided by ultrasound, they successfully bypass the P-gp pumps, avoiding drug efflux [G.Husseini, personal communication, June 28, 2021], and gather at the site of the tumor cells through the enhanced permeability and retention effect (EPR) as shown in Fig. 4 [17]. The EPR effect describes an increase in the concentration of NMs in cancerous cells, avoiding healthy tissues and thereby increasing the collection of drugs in the tumor cells [18]. This significantly improves the therapeutic efficacy and destroys a greater number of cancer cells. Moreover, this process has proven to be most effective when ultrasound is induced for 2 minutes and at a low frequency. As a result, the NMs surpassing the P-gp pumps would be allowed to reach the nucleus and destroy the cancer cells, thereby overcoming MDR [19]. Therefore, the use of NMs and ultrasound to provide targeted delivery of drugs can ensure the protection of surrounding healthy tissues while increasing the chance of successful treatment of the tumor by eliminating a significant portion of cancer cells.

4. Evaluation

4.1. The Utilization of Nano-biosensors

Although the detection of cancer cells can be made easier through the use of nanowire sensors, the detection level of the sensor may be affected by several issues. The main problem is shielding which can occur when the nanowires become charged, since they cover the surface of the FET sensor, leading to a reduction in the sensitivity of the FET. This shielding decreases the level of detection and hinders the sensor's ability to detect the change in conductance, consequently making it more difficult to determine whether the cells are healthy or cancerous. Moreover, shielding of the FET sensor can also occur due to Debye screening, where ions in the electrolyte solution used for doping of SiNW can accumulate around the bound analyte on the and repel the charges present on them. Due to this repulsion, there is a reduction in the charge that can be sensed by the FET which would impose a clear limitation in detecting small tumors [20].

Moreover, other factors which affect level of detection include background noise and the binding of the healthy cells with the sensor. To avoid background noise, SiNW usually operates at low frequencies. However, background noise may still be present as static noise due to electromagnetic interference between the wires. This static noise would decrease the limit of detection and in turn decrease the precision of the sensor, making the detection of tumors more difficult [21]. Furthermore, the surrounding healthy cells may cover the SiNW as they bind with it, thereby limiting the sensitivity and detection level of the FET by obstructing potential analyte from binding with the bioreceptor [22]. Therefore, biosensors contain limitations which can hinder their ability to precisely detect cancer cells.

4.2. The Usage of Targeted Delivery

While the usage of nanomaterials such as liposomes is effective in the targeted delivery of drugs to cancer cells, it has some limitations. Firstly, the instability of liposomes can result in a shorter shelf-life. Their physical instability can be a

result of drug leakage from the liposomes or the fusion of these liposomes to form larger particles. Both processes, drug leakage and change in liposome size, influence the in vivo performance of the drug formulation, and therefore may affect the therapeutic index (relative safety) of the drug [23]. Secondly, the encapsulation efficiency of the liposome and the drug can be a significant issue. As one of the constituents of liposomes is lipids, liposomes require a certain amount of lipids to be present in them to be able to encapsulate the drugs and deliver them efficiently to the target site. However, lipids in high doses can be toxic to the cells which is caused due to nonlinear pharmacokinetics. This means that an increase in the dosage of the drug can cause a disproportionate increase in the concentration of the drugs at the target site [23]. Lastly, nanoparticles may also chemically react with each other to produce reactive oxygen species (ROS), which are highly reactive molecules formed as a by-product of metabolism of oxygen. ROS can cause oxidative stress, DNA and protein damage as well as inflammation, leading to increased toxicity. These can cause neurodegenerative diseases such as Parkinson's disease and Alzheimer's. For instance, Silica nanoparticles at high doses can cause oxidative stress, consequently inducing brain damage and a reduction in cell viability [24]. In conclusion, nanomaterials such as liposomes can cause problems due to their instability, toxicity resulting from high lipid content, and oxidative stress.

4.3. Costs of Nanotechnology

Although nanotechnology plays an important role in the field of medicine and drug delivery, the costs of nanotechnology pose a notable challenge to companies and patients [25]. In other words, there is an existing gap between technology development and the efficient commercialization of nanotherapeutics. Small-and-medium-sized enterprises (SMEs) are currently driving the commercialization of nanotherapeutics as big pharmaceutical companies show less interest to invest in nanotherapeutics due to low profits [25]. This means that it has been difficult for SMEs to establish a partnership with big pharma firms willing to adapt new established technology to the market. Moreover, nanomedicine production poses a notable high per-unit -cost to companies. Due to these diseconomies of scale in nanomanufacturing, an existing high acquisition costs for nanotherapeutics occurs, which limits its success to be introduced to daily clinical practices. In numbers, the acquisition costs of nanotherapeutics may reach to tens of thousands of dollars per patient per year, resulting in higher selling prices [26]. For example, such costs pose a problem in European countries where they lack translating successful research findings into nanodrugs [26]. Therefore, companies will struggle to make profit as it is estimated that those companies need to generate about 2870 million US dollars in revenue to achieve profit [27]. This represents a major obstacle to commercialization, resulting in undermining the future success of nanomedicine in the market.

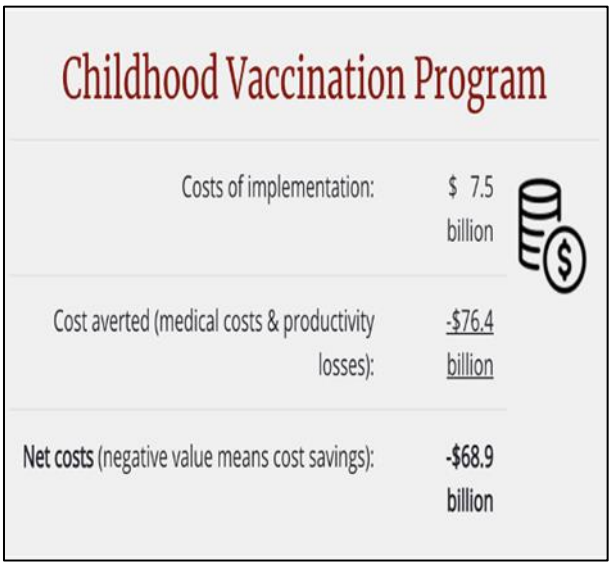

Figure 5 CEA outcome showing cost savings.

However, high acquisition costs can still be justified by performing a cost-effectiveness analysis (CEA) for nanotherapeutics [25]. Cost-effectiveness analysis examines the costs and health outcomes of alternative intervention [28]. There are two possible outcomes that occur when net costs are positive/negative. The first outcome is when the net costs of an intervention are positive, which is when the more effective intervention is more costly, the results are presented as cost-effectiveness ratio. When the more effective intervention is more costly, the net costs are positive and the results are presented as cost-effectiveness ratio. A cost-effectiveness ratio is the net cost divided by changes in health outcomes [28]. An example is cost per case of disease avoided or cost per death prevented. The second outcome

is when the net costs of an intervention are negative, which is when the more effective intervention is less costly, the results are shown as net cost savings. An example is shown in Fig. 5 [28]. Currently, the use of CEA studies in the nanomedicine field is still in its infancy. Making the use of CEA is a missing crucial factor that might enhance where nanotherapeutics stand in the market. Firstly, CEA studies concentrate on controlling healthcare costs while maintaining quality care, hence creating value for money in the healthcare sector and cost-savings for the society [26]. Accordingly, nanomedicine products are candidates for reimbursement, shifting its high acquisition costs elsewhere while contributing to affordable care. Secondly, the use of CEA could serve as a tool to improve the future of the nanomedicine market due to it serving as a basis for reimbursement [26]. This will attract big pharma firms to invest in establishing new drugs and thus, fuelling the nanomedicine market. Therefore, the use of CEA is indeed an important key factor for the future of economic success of nanomedical applications.

5. Conclusion

Cancer is a global concern that affects millions of people; currently, there are limited efficient methods to detect and treat cancer let alone a cure, causing an increased need for highly effective and non-damaging detection and treatment techniques. This need for such novel methods is attributed to the low effectiveness and efficiency of conventional methods for early detection of cancer cells such as Magnetic Resonance Imagining (MRI), Computerized Tomography (CT), and Positron Emission Tomography (PET). These methods fail to identify tumors at an early stage and can only detect them once they are big enough. Also, it is difficult to differentiate between benign and malignant tumors using these conventional methods of detection, requiring the patient to undergo invasive surgery. As for the issues with treatment, conventional cancer treatments such as chemotherapy have a high possibility of destroying the surrounding healthy tissues at the tumor site due to inefficient targeted delivery. The inefficient targeted delivery, coupled with the increased exposure to chemotherapy is a serious issue for patients who relapse because the recurring cancer cells develop MDR, making the anticancer drugs ineffective. These shortcomings in the conventional methods call for the need to use more advanced and potent techniques to identify and treat the cancerous cells at the earliest.

A breakthrough in the field of nanotechnology has made it possible to develop revolutionary methods for the detection and treatment of cancer. Firstly, to tackle the issue of early detection, nanotechnological devices known as nanowire biosensors can be used. The bioreceptor component of the biosensor binds to the analyte (cancer cells); the transducer converts this binding to a detectable signal; the signal processor converts this detected signal into information which can then be used to measure the concentration of the analyte, hence detecting cancer at an early stage. Secondly, to carry out successful targeted delivery of the drugs, nanomaterials can be employed. Nanomaterials such as liposomes are made up of components such as lipids and cholesterol, which are also present in the cell membrane; the similarity in the composition of liposomes and the cell membrane helps to increase the deposition of the drug into the tumor cells through a highly efficient lipid-lipid interchange process. Also, the small size of the nanomaterials enables them to be easily absorbed by the targeted tumor cells. These properties allow for a smooth and efficient targeted delivery process. Moreover, the nanomaterials need to be led to the tumor cells, which is facilitated through ultrasound. The energy from the ultrasound rays can result in twice as much accumulation of the nanomaterials at the tumor site, which improves the treatment process significantly. Therefore, nanotechnology-based approaches are effective in solving the issues associated with conventional detection and treatment methods of cancer.

However, it is essential to address some of the drawbacks of these approaches. First, the results yielded by nanowire biosensors can be affected by several factors such as background noise, charge screening and the binding of the cancer cells on the sensor. The presence of background noise can alter and distort the detected signals, hence producing inaccurate results. The charges on the nanowires can give rise to screening effects resulting from the repulsion forces between the analyte (cancer cells) and the nanowires. As a result, the sensitivity of the biosensor decreases giving less precise results. Second, while nanomaterials such as liposomes by virtue of their small size effectively administer anticancer drugs to specifically targeted sites, they can be found to be unstable and potentially toxic. The instability can result from drug leakage from the liposomes or the fusion of liposomes causing a change in liposome size, affecting the performance of the drug and causing safety issues. Moreover, the lipid content in the liposomes, which is an essential factor for encapsulating the drugs, must be at optimum levels. An increase in the lipid content could result in a disproportionate increase in the concentration of the drugs at the target site as the dosage of the drug increases, which is toxic to the cells. In addition, the nanoparticles can chemically react with each other to produce ROS, which can damage the DNA, cause oxidative stress, and consequently result in neurodegenerative diseases such as Parkinson's and Alzheimer's.

Moreover, some of the main challenges encountered during the preparation of this research paper were to find the appropriate sources to support the proposed ideas. Due to these nanotechnological approaches being relatively new, limited research material is available. Additionally, after finding the information, it was challenging to integrate all the

ideas to present logical and convincing information. The team also conducted an in-depth evaluation of the costs of nanotechnology by studying the commercialization of nanotherapeutics and examining the cost-effectiveness analysis (CEA) for nanotherapeutics. Therefore, by conducting thorough research on the usage of nanotechnology in the detection and treatment of cancer, we encourage health institutions across the globe to adapt and incorporate nanotechnological-based methods while also urging them to make these services accessible to as many people as possible.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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