Cancer Detection and Treatment in Human: Nanotechnology Application; an advanced Approach.

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Abstract

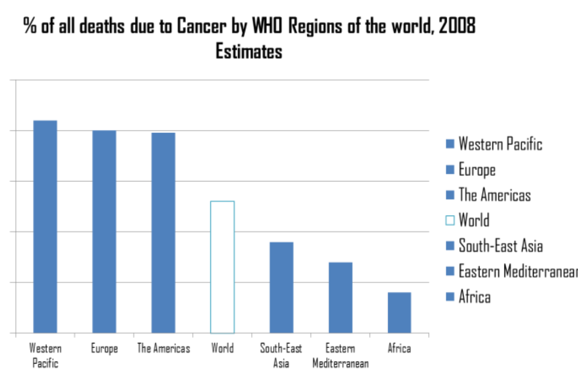
Cancer is a complex disease caused by genetic instability and accumulation of multiple molecular alterations in human beings. Earlier efforts of diagnostic and prognostic classifications do not reflect the whole clinical heterogeneity of tumour and are insufficient to make predictions for successful treatment and patients' outcome. It may be noted that current advances in nanotechnology have offered new hope for cancer detection, prevention and treatment. Nanotechnology has wide-ranging applications such as drug synthesis and delivery, cell surgery and therapy, early disease diagnosis and prevention, biosensors and medical implants. Nanoparticles formulation are advantageous over conventional chemotherapy because they can incorporate multiple diagnostic and therapeutic agents and are associated with significantly less adverse effects due to selective accumulation to tumour tissue. Hence, nanoparticles can further be engineered to target specific tumour cells that express particular cell surface molecules. The selection of appropriate targets, component materials, formulation strategies and characterization methods are critical to achieving successful outcomes. The study is geared towards reviewing aims at integrating some recent advances of nanotechnology with high potential for improving the cancer detection and treatment in humans.

Keywords: Nanoparticles, molecular therapy, Nano-medicine and nanotechnology.

1. BACKGROUND

Cancer medically known as malignant neoplasm is a broad group of various diseases, all involving unregulated cell growth. In cancer, cells divide and grow uncontrollably, forming malignant tumours and invade parts of the body. However, not all tumours are cancerous. It is a potentially fatal disease caused mainly by environmental factors that mutate genes encoding critical cell-regulatory proteins. The resultant aberrant cell behaviour leads to expansive masses of abnormal cells that destroy surrounding normal tissue and can spread to vital organs resulting in disseminated disease, commonly a harbinger of imminent patient death.

Cancer remains a cause of considerable morbidity, mortality. It results to 13% of all deaths worldwide. From Statistics, It is estimated that if current trends continues, there will be 22 million new cases of cancer worldwide occurring each year by 2030 (Cancer Research UK 2013).



As at present, Cancer has no definite cure but there have been considerable improvements in the way cancer is treated as current advances in nanotechnology have offered new hope for cancer detection, prevention and treatment. Several cancer detection methods are emerging which use nanotechnology to see right into the depth of the body as tumours begin to form, long before they become detectable by conventional means. Some of them which included Scanning and Imaging cancerous tumours and detecting cancer by analysing tissue samples.

Problem Statement

Before now, there were different ways cancer could be detected and treated depending on the type of cancer; which includes but not limited to surgery, chemotherapy, radiation. But all these have numerous side effects namely; in surgery, sometimes only part of the tumour can be removed, chemotherapeutics suffer from non-specific distribution, with only a small fraction of drugs reaching the tumour, tissue damage also occurs as a result of radiation. It may be noted that current advances in nanotechnology have offered new hope for cancer detection, prevention and treatment. The study is geared towards reviewing aims at integrating some recent advances of nanotechnology with high potential for improving the cancer detection and treatment in humans.

1.1 Aim and Objectives of the Research

The aim of this research is to:

(a) Examine the ineffectiveness of many cancer treatments and their side effects.
(b) Address the types and characteristics of Nanoparticle.
(c) Show how nanoparticles can be used as drug delivery system and imaging devices to increase the efficacy per dose of therapeutic or imaging contrast agent.
(d) Show how nanoparticles will be further developed to improve their functionality in cancer treatment and imaging.

1.2 Scope of Work

This work will use the principle of Sciences, Engineering, chemistry and medicine (particularly in the context of an improved understanding of fundamental biology), with broad applications for molecular imaging, molecular diagnosis and targeted therapy.

1.3 Limitation of Study

In Nanomedicine, particles are engineered so that they are attracted to diseased cells, which allow direct treatment of those cells. This technique reduces damage to healthy cells in the body and allows for earlier detection of disease. No human trials have been performed yet; they are still at least a few years away but pre-clinical trials reveal that a single intravenous Nanoparticle injection eradicated 100 percent of tumours in mice when exposed to near-infrared light.

Conventional Method of Cancer Detection

Existing cancer screening methods include:

1. The Papanicolau test for women to detect cervical cancer and mammography to detect breast cancer,
2. Prostate-specific antigen (PSA) level detection in blood sample for men to detect prostate cancer,
3. Occult blood detection for colon cancer
4. Endoscopy, CT scans, X-ray, ultrasound imaging and MRI for various cancer detection

NB: some of the screening methods are quite costly and not available for many people.

2. REVIEW OF NANOTECHNOLOGY

Nanotechnology is the creation of useful materials, devices, and systems used to manipulate matter at an incredibly small scale—between 1 and 100 nanometres. This emerging field involves scientists from many different disciplines, including physicists, chemists, engineers, information technologists, and material scientists, as well as biologists. Nanotechnology is being applied to almost every field imaginable, including electronics, magnetics, optics, information technology, materials development and biomedicine.

Nanoscale devices are one hundred to ten thousand times smaller than human cells. They are similar in size to large biological molecules ("biomolecules") such as enzymes and receptors. As an example, haemoglobin, the molecule that carries oxygen in red blood cells, is approximately 5 nanometers in diameter. Nanoscale devices smaller than 50 nanometers can easily enter most cells, while those smaller than 20 nanometers can move out of blood vessels as they circulate through the body.

Because of their small size, nanoscale devices can readily interact with biomolecules on both the surface and inside cells. By gaining access to so many areas of the body, they have the potential to detect disease and deliver treatment in ways unimagined before now.

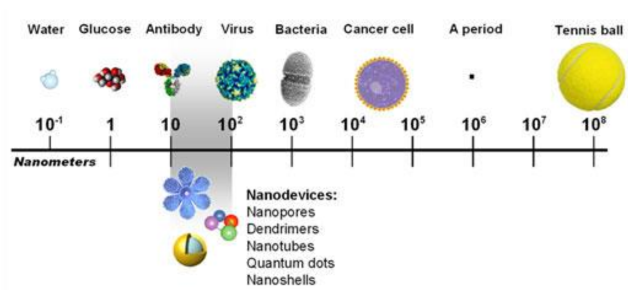
2.1 Nanotechnology and Cancer

Nanotechnology allows researchers to build new tools that are actually smaller than cells, giving them the opportunity to attack cancer cells at the cellular and genetic level. This technology not only enables health practitioners to detect cancer earlier but also holds the promise of stopping cancer before it even develops.

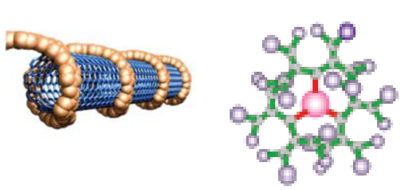
Based on computer chip technology, diagnostic devices such as nanoarrays are thousands of times more sensitive and accurate than current techniques. Because of their size, multiple lab tests can be done more rapidly and at a much lower cost using one nanodevice instead of many. Nanoshells can be linked to antibodies that recognize tumour cells. Once they are taken up by the cancer cells, near-infrared light is applied, killing only the tumour and leaving neighbouring, healthy cells intact.

Currently, Scientists are engineering nanoparticles such as dendrimers to seek out and destroy cancer cells. This amazing technology can be customized for targeted drug delivery, improved imaging, and near real-time confirmation of cancer cell death.

This revolutionary approach is so precise; doctors will be able to design a unique treatment for an individual's own medical and genetic profile.



Nanotechnology has been developing rapidly during the past few years and with this, properties of nanomaterials are being extensively studied and many attempts are made to fabricate appropriate nanomaterial. Due to their unique optical, magnetic, mechanical, chemical and physical properties that are not shown at the bulk scale, nanomaterials have been used for more sensitive and precise biomarker detection. Nanomaterials that have been applied to sensing cancer biomarkers vary from gold nanoparticles, quantum dots, magnetic nanoparticles, carbon nanotubes and nanowires



3. DETECTION AND TREATMENT OF CANCER USING NANOTECHNOLOGY.

3.1 Detection of Cancer using Nanotechnology

Several cancer-detection techniques are emerging which use nanotechnology to see right into the depths of the body as tumours begin to form, long before they become detectable by conventional means.

- **Scanning and Imaging Cancerous Tumours**

  Imaging techniques, such as Magnetic Resonance Imaging (MRI) or Computed Tomography (CT) scans, can detect the presence of tumours in the body. However, by the time the tissue has altered enough to be detected by this method, the cancer has progressed to a fairly advanced stage, which may make the treatment less effective. It is also not clear from these scans whether the tumour is cancerous or benign - a further stage of tissue analysis is needed to confirm this.

  To make these scans a more robust method of testing for cancer at as early a stage as possible, a "tagging" method is required - something which will selectively bind to cancerous cells and drastically increase their visibility scans.

  It seems that nanotechnology will be able to provide the solution to this problem. Metal oxide nanoparticles, which generate a very strong signal on CT and MRI scans, can be coated with antibodies which bind to a certain receptors which are produced in greater quantities in cancerous cells than in normal cells. The nanoparticles would be concentrated around cancer cells, allowing cancerous tumours to be identified very easily. The strong signal means that very early stage tumours could be detected by this technique.

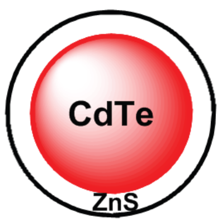
- **Detecting Cancer by Analysing Tissue Samples**

  When it is suspected that a patient has cancer, the only way to verify it for sure is to take a biopsy - a sample of tissue which is analysed for biomarkers - characteristic chemicals created by the disease. A technique called a fluorescent immunoassay (FIA) attaches a fluorescent "label" chemical to these biomarkers, allowing the disease to be detected.

  This process could be significantly enhanced using nanotechnology. Researchers at Princeton University developed a nanomaterial, called D2PA, which amplifies the light from the fluorescent labels. This allows the cancer to be detected much earlier, when the light would normally be much too weak to detect.

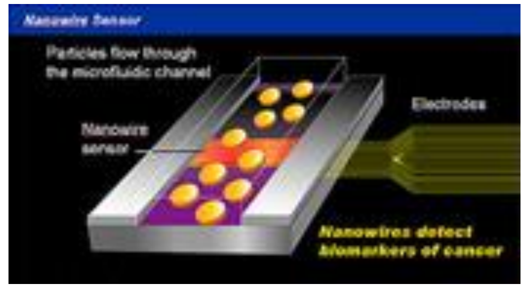
Because cancer is not technically one single disease, but a huge number of similar diseases, there are hundreds or thousands of biomarkers which, if analyzed properly, could indicate the presence of a specific type of cancer.

An immunoassay using markers containing quantum dots could provide a much more detailed analysis of a blood or tissue sample. The wavelength of the light emitted by quantum dots depends on their size. By attaching quantum dots of different sizes to the biomarkers for different types of cancer, a single analysis could provide doctors with a spectrum of emitted light identifying the profile of healthy and cancerous cells in the individual's body. This could help to identify when cancer had spread to other parts of the body, allowing the best possible treatment regime to be devised.

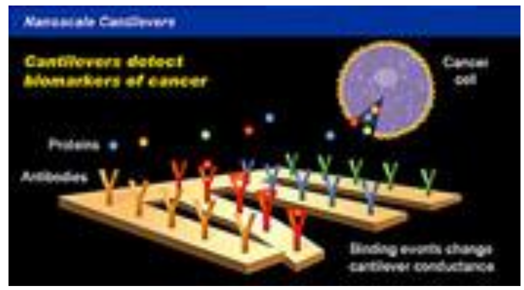


Quantum dot

- **Nanoscale cantilevers and nanowire sensors** can detect biomarkers of cancer from a single cell, which heretofore was unimaginable. These tiny levers which are anchored at one end can be engineered to bind molecules that represent some of the changes associated with cancer. They may bind to altered DNA sequences or proteins that are present in certain types of cancer. When these molecules bind to the cantilevers, surface tension changes, causing the cantilevers to bend. But monitoring the bending cantilevers, scientists can tell whether molecules are present. Scientists hope this property will prove effective when cancer –associated molecules are present—even in very low concentrations—making cantilevers a potential tool for detecting cancer in its early stages.



Nanowires can detect the presence of altered genes associated with cancer.



Cantilevers—microscopic, flexible beams—can provide rapid and sensitive detection of cancer-related molecules.

3.2 Treatment of Cancer using Nanotechnology

- **Nanotubes:** An interesting property of nanotubes is that they absorb near infrared radiation. This causes them to heat up very quickly. Once the nanotube is attached to the cancer cells, Dai, uses a near infrared laser beam to heat nanotubes until it kills the cancer cells. This method is still at the testing stage.

- Gold Nanoshells have a core of silica and a metallic outer layer. These nanoshells can be injected safely as demonstrated in animal models. Because of their size, nanoshells will preferentially concentrate in cancer lesion sites. This physical selectivity occurs through a phenomenon called Enhanced permeation retention (EPR).

- Another potential treatment involves absorption of light by gold nanoparticles *(Pitsillides et al., 2003).* The method involves gold-coated nanoparticles conjugated to recognition ligands.

- Finally, the nanoparticle method for direct cell destruction to be discussed is the magnetic nanoparticle hyperthermia method (Jordan et al., 1999). It is hypothesized that the relatively old concept of hyperthermia can be combined.

4.0 Impact of Nanotechnology to Cancer Detection and Treatment

- Nanotechnology protects drugs from being degraded in the body before they reach their target.
- It enhances the absorption of drugs into tumours and into cancerous cells themselves.
- It allows for better control over the timing and distribution of drugs to the tissue, making it easier for Oncologists to assess how well they work.
- It prevents drugs from interacting with normal cells, thus avoiding side effects.

4.1 Implications of Nanotechnology and Cancer detection and Treatment

Of course, nanomedicines aren't without limitations;

1. **The need for biocompatible and stable Nanoparticles:** The ability to reproducibly manufacture nanomedicines at large scales with high levels of control over the physicochemical properties remains a major obstacle. Though many labs can make nanomedicines at the milligram levels for proof-of-concept in vitro studies, the costs and manufacturing challenges associated with making large-scale batches of the same quality remain great.

2. **Cost:** New technology often doesn't come cheaply, and so far nanomedicines are no exception although the increased costs come with documented advantages: Because the nanomedicines are less toxic to healthy tissue, they afford patients a significantly better quality of life than their molecular counterparts.

3. **Environmental impact:** The same material properties that make nanoparticles appealing for cancer therapy and other applications may have unintended effects on human health and the environment. Although the acute toxicity of many nanomaterials appears to be low, studies that evaluate chronic toxicity are still largely missing from the scientific literature. However, the potential health risks associated with the manufacture and use of nanomaterial must be balanced by the benefits that nanotechnology has to offer society for cancer therapy and beyond

5.0 CONCLUSION

Cancer is an issue which touches everyone at some point in their lives. A huge amount of research effort is being poured into research for diagnosis and treatment of the condition. Whilst the treatment of many common types of cancer has come on in leaps and bounds over the last few years, there is still no absolute cure for any form of cancer. Nanomedicine will change the way cancer is diagnosed, treated and prevented. Nanomedicine for cancer has the ability to improve health care dramatically. By combining the principles of engineering, chemistry and medicine – particularly in the context of an improved understanding of fundamental biology – the field of nanotechnology will move closer to making the elusive 'magic bullet' a reality.

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