GOING SMALL FOR BIG ADVENTURES
CANCER TREATMENT USING NANOTECHNOLOGY

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Abstract

Nanotechnology is a very fast developing field of science. This paper reviews the most important studies and shows how development in nanomedicine might ultimately offer a better cancer treatment comparing to the current therapies. It shows the positive and negative sites of the actual examinations of nanogold particles and gives strong evidence that more tests should be performed.

Introduction

In the last few years nanotechnology (NT) has developed and fundamental research has been conducted in many areas including mechanics, electronics, plastics, energy, materials science and medicine. With its good future prospects nanotechnology has been highly-sponsored (one branch of NT, nanomedicine (NM) has been funded with $3.5 billion by the European Union Government between 2007-2013).
In the 21st century most kinds of NT are promising to be key fields of future science development. Nanotechnology is the general name for a whole set of ways and techniques to create a variety of structures with nanometer-size (at least one dimension of 1 to 100 nanometers, where one nanometer is 10^{-9}m), which is at the level of individual atoms and molecules.
However NT is not only limited to the nanoscale. It also deals with structures on the micron scale because it can be combined from many nanomolecules to form larger structures.

NM, which is an area of biomedical research, uses the nanoscale for tests and treatments and it is also used in its products (for example nanosilver particles in deodorants, which have antibacterial properties). There is a large amount of research and hypothesis being made about the use of nanomolecular particles. For this reason most medical uses of NT are hypothetical so NT is a more theoretical than practical industry.

NT might have huge impact in future medicine. Diagnosis might be quicker and more precise, drugs might be delivered in exact proportion, and treatments might be more reliable and much faster without negative aspects. Scientists are promising development in NM for many aspects like drug delivery, tissue engineering and cancer diagnosis and treatment.

And this is not a 'Star Trek'. There have been done researches and experiments (in vitro and in vivo) based on NT knowledge.

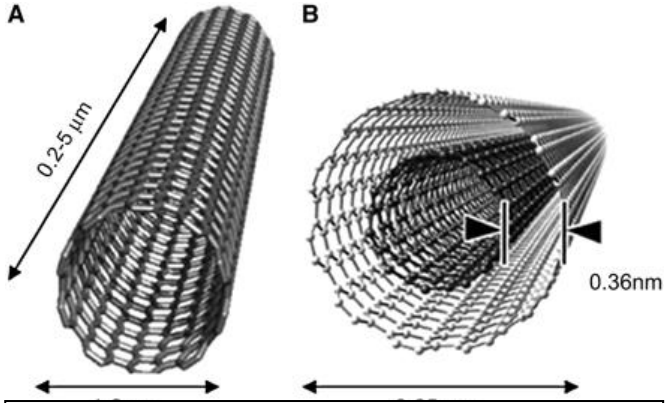

Figure 1

One of the latest researches are carbon nanotubes (figure 1), which are allotropes of carbon making molecular-scale tubes. Carbon nanotubes have been tested by research team led by Bin Kang and Yaodong Dai at Nanjing University and the Georgia Institute of Technology (2009) with the aim of cancer treatment. The nanotubes were attached to folic acid. By this they were most likely to be absorbed by tumours because of the folic acid receptors on the abnormal cells. After applying the nanotubes inside the cancer cells scientists exposed them for a fraction of second to a near-infrared flash. The effects were positive, because of the fact that the cells without the nanotubes were almost completely transparent while the abnormal cells with the

nanostructures of carbon inside were overheated with the outcome of destroying cancer cells. Final result was that after 20 seconds 85% of the cancer cells were destroyed and 90% of the normal cells remained intact.

Another experiment done by researchers from the Jagiellonian University (2000) was performed in vivo on mice. Scientists were relying on the fact that the immune system may assists expansion of the tumour because it does not recognize the abnormality of the cells. Researchers modified the bacterium of the salmonella by adding an antibody fragment which was recognizing the cancer cells. As a result the immune system started fighting the abnormal cells.
Although the experiment had positive results it is impossible to use such a treatment on humans. The main problem is the construction of the blood veins in mice and humans by which the bacteria can travel.

Scientists are boldly saying that nanotechnology is a way forward to develop medicine and it is going to have many positive aspects. One of the basic aims is to improve the NT to the state where nanostructures made by the humans would be equal to this made by the nature.

Discussion

Before the paper discuss it is important to describe what cancer is.

Cancer

In the 21st century cancer is one of the most common causes of deaths. It is a class of disease caused by disorder of the cell growth during the cell division (figure 2) – the genetic material of the cell (DNA) becomes changed or damaged. This mutation results in the destruction of the cell and the dislocation to the other, surrounding healthy cells. Cancer cells do not seem subject to regular control by nerves and hormones, they do not die when they should and they divide much faster, in an uncontrolled way, than the normal body cells.

Statistics from 2009 published by the World Health Organization show that in 2004 7.4 million people died because of cancer (which is 13% of the all deaths).

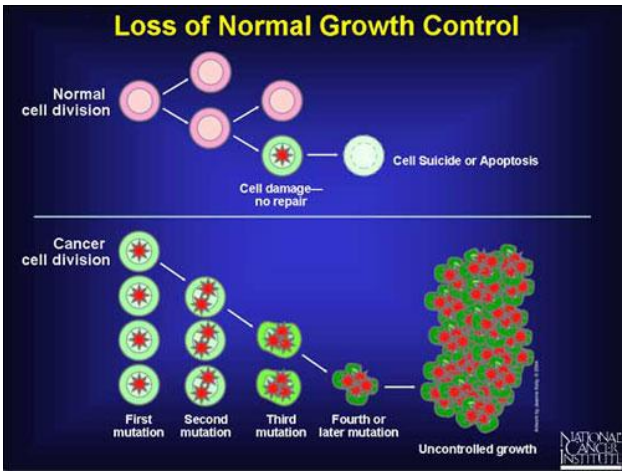

Figure 2

A mass of the abnormal tissue is called tumour (or tumor). Scientists distinguish two types of tumours: benign and malignant. The first one does not spread to other parts of the body, so it is easier to treat. The second one is much more harmful for the reason that it can spread to other parts of the body where it causes damages by producing more mutated tissue.
The common risk factors are growing older, cigarettes, radiation, certain chemicals, certain hormones, viruses, bacteria, poor diet, obesity, alcohol and family history of cancer.
There are many types of the cancer treatments. The most common are surgery, radiation therapy and chemotherapy.

Remaining cures are hormones therapy, bone narrow and stem cells transplantation, immunotherapy, the use of hyperthermia, targeted therapy, anti-angiogenesis drugs and the others. Different treatments of the cancer, like surgery, are local therapy (which are in the specific area, just in one part of the body) and, like chemotherapy, systematic therapy (destroys mutated cancer cells throughout the body).
Today's cancer manipulations have many disadvantages. After almost every therapy or combination of the therapies there are short-term (acute) and long-term (chronic) problems, which are called side effects. Side effects may cause inconvenience, discomfort, serious illness and even death.
In one of the most fearful treatment, which is chemotherapy, patients are given cytotoxic drugs that travel all around the body causing detriments with the hope of reaching the abnormal cells. This treatment has a lot of side effects; the most common are low white blood cell count, low red blood cell count, low platelet count, nausea, vomiting, hair loss and fatigue. However chemotherapy is not the only treatment which causes so many problems. Other cures also have negative aspects like (after surgery and/or radiation) bleeding, damage to internal organs, reaction to drugs used, pain, infection, slow recovery, fatigue, skin changes, nausea, vomiting and/or loss of appetite. As well as these physical harmful side effects there are also negative psychological results (like fear or depression).

Nanogold

Gold (chemical element with the symbol Au), except of its esthetic properties, is a very important part in medicine and stomatology, for example compounds of this element are being used as a therapeutic agent in an rheumatoid arthritis (administered intramuscularly). This element is ideal for the many medical treatments because of the absence of toxicity and biological hazard.

While the normal bulk gold is shiny, gold in color, it conducts the electricity and it is inert, scientists discovered that gold particles reduced to the nanometer scale (figure 3) change their properties. Firstly, there is a change of color (from deep red to black) which depends on the size of nanoparticle of Au and its distance from the others. Secondly the gold in nanoscale is no longer a metal but it becomes a semiconductor. Another point is that Au in so small size is a good catalyst. All these results have been examined and tested in the laboratories.

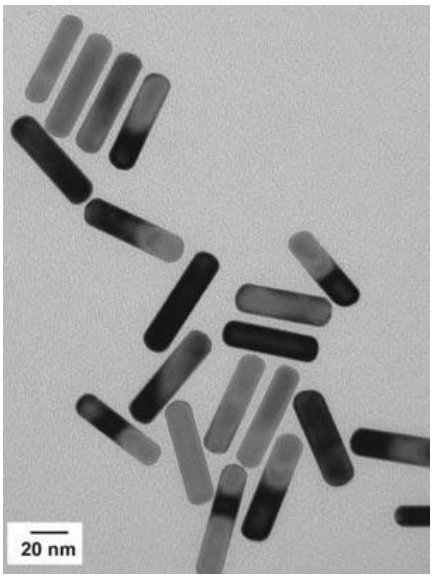

Figure 3

The nanoparticles of Au absorb the light and transmute it into the thermal energy. Absorption of the flash depends on the shape of the nanogolds. In most experiments the nanogold which is used absorbs the near-infrared light.
Researches have shown that high temperature can kill cancer cells. Because of this knowledge doctors are using a hypothermia treatment, in which tissues are exposed to the temperature of 45 ºC. The elimination of cells by heat capacity has been also tested with nanoscale participles including nanogold. The nanogold particles, located in the abnormal cells, after single exposure to a near-infrared laser are heated up to 70ºC. Important point is that the light passes harmlessly through the tissues without nanoparticles of Au inside.

Even if the temperature is not so warm this action makes the changes. Lower temperature enhances the effectiveness of the other treatments, like chemotherapy, thus the cancer cells are more susceptible for the chemical drugs given to the patient.

The first discovery of the heat capacity connected with nanoparticles of gold was detected by researchers from the University of Southern California and the Georgia Institute of Technology (2005). They found out that the nano Au particles attach themselves to the cancer cells and receive enough heat energy to destroy them. Because of the positive results researchers are looking forward to collect enough data and examination to find how the small particles of gold heated up by a laser can annihilate the cancer cells. The use of the heated nanogold particles looks promising for the future medicine, however it still needs more development and statistics.

Before the new technique or drugs release to the market many tests are needed to be done, including: the test on the tissue cultures, the examinations in vivo on some animals and the analysis on the humans. These processes enable scientists to check properties of the target and if the examined object does not have any harmful disadvantages.
Despite many positives about the actual research and its outcomes some researchers are concerned about the future use of the nanoparticles. They are disturbed about the small amount of knowledge about health and safety.

Use of the nanogold with laser has already been tested in vivo.
Geoffrey von Maltzahn, MIT graduate student, with Sangeeta Bhatia, professor in the Harvard-MIT Division of Health Sciences and Technology and in the Department of Electrical Engineering and Computer Science, a member of the David H. Koch Institute for Integrative Cancer Research at MIT and a Howard Hughes Medical Institute Investigator, have been conducting experiments on mice with tumors with taking into an account the tiny pores from the blood vessels located near the abnormal cells. The results were positive because within a few days the cancer cells disappeared and the mice lived for about three months while remained, which were not treated by the nanoparticles or were just given the nanogold or the laser treatment, died few days later.

These experiments showed us that the development and use of nanogold participles for the cancer treatment is promising, however on the other hand it is very important to take into the account that we still do not know what might happen after placing the nanoparticles of Au for any longer time than three months and what might happen if our organism will not be able to eject it. The nanoparticles are small enough to infiltrate almost everywhere which may be great for the cancer treatment however potentially harmful to the non-cancer cells and there are still no known ways to prevent the harmful effects which might happen. For today day many scientists are concerned about too fast development of the nanotechnology and are pointing that special disposal techniques are firstly need to avoid the negative sides.

Another important point is that if the new techniques of fighting cancer, based on NT, will be available there will be people who will not be able to afford it, so if necessary they will need to use the other therapies, while the nanotechnology abnormal cells treatment might only be available for a certain group of people.

Conclusion

The problems of today's cancer therapies - chemotherapy and radiation therapy- are that the cells which are affected are not only cancer cells but they are also healthy cells.
In view of the fact that current therapies have many negative effects, the future use of nanogold participles, would be better way to fight cancer; they would target only abnormal cells without any or with few almost unnoticeable side effects.

Nanotechnology is a very fast developing industry however for the present moment NT is not known enough to be approved for use in medicine to treat cancer.
Because of not completely known toxicology and the behavior of nanoparticles of Au in the human body no cancer treatment using nanogold molecules is yet permitted.
Any nanoproducts which may be used in the future, including nanogold particles, are not yet known to be completely safe.

Both, positive and negative aspects suggest very strong that more experiments and researches should be conducted to develop medicine in terms of cancer treatment.

References:

Image references:

Title picture: http://www.wifinotes.com/nanotechnology/img/nanomedicine.jpg
Figure 1: http://jnm.snmjournals.org/content/vol48/issue7/images/large/1039fig1.jpeg
Figure 2: http://www.cancer.gov/PublishedContent/Images/images/documents/cancer4-new.jpg
Figure 3: http://web.mit.edu/newsoffice/2009/goldcancer-enlarged.jpg

Text references:

[1] What is Nanotechnology?

http://www.nano.gov/html/facts/whatIsNano.html

[2] Nanotech not a nano-sized threat
http://marketplace.publicradio.org/shows/2007/07/31/PM200707314.html

[3] Nanomedicine - The Future of Medicine
http://www.medicalmegatrends.com/nanomedicine.html

[4] Carbon nanotube

http://en.wikipedia.org/wiki/Carbon_nanotube

[5] "Nanobombs" shock cancer cells

http://www.materialstoday.com/view/1415/1st-smethermal-solar-thermal-materials-equipment-and-technology-conference/

[6] UJ scientists research whether Salmonella bacteria may help fight cancer
http://www.eduskrypt.pl/uj_scientists_research_whether_salmonella_bacteria_may_help_fight_cancer-info-26661.html

[7] What is Cancer? What Causes Cancer?

http://www.medicalnewstoday.com/info/cancer-oncology/

[8] Defining Cancer

http://www.cancer.gov/cancertopics/cancerlibrary/what-is-cancer

[9] WHO, IAEA join forces to fight cancer in developing countries
http://www.who.int/mediacentre/news/releases/2009/who_iaea_cancer_programme_20090526/en/index.html

[10] Types of Treatment
http://www.cancer.gov/cancertopics/treatment/types-of-treatment

[11] Chemotherapy Side Effects Fact Sheets
http://www.cancer.gov/cancertopics/coping/chemo-side-effects

[12] Chemo side effects
http://www.cancer.org/Treatment/TreatmentsandSideEffects/TreatmentTypes/Chemotherapy/UnderstandingChemotherapyAGuideforPatientsandFamilies/understanding-chemotherapy-chemo-side-effects

[13] What are the risks and side effects of surgery?
http://www.cancer.org/Treatment/TreatmentsandSideEffects/TreatmentTypes/Surgery/surgery-risks-and-side-effects

[14] What are the side effects of radiation therapy?
http://www.cancer.org/Treatment/TreatmentsandSideEffects/TreatmentTypes/Radiation/RadiationTherapy-WhatItIsHowItHelps/radiation-therapy-what-it-is-side-effects

[15] Emotional Side Effects
http://www.cancer.org/Treatment/TreatmentsandSideEffects/EmotionalSideEffects/index

[16] Gold
http://www.accessnano.org/teaching-modules/gold

[17] Nanogold Does Not Glitter, But Its Future Looks Bright
http://www.sciencedaily.com/releases/2004/04/040428062059.htm

[18] Hyperthermia
http://www.cancer.org/Treatment/TreatmentsandSideEffects/TreatmentTypes/hyperthermia

[19] Nanogold helps lasers seek out and destroy cancer tumours
http://www.nanomagazine.co.uk/index.php?option=com_content&view=article&id=497%3Ananogold-helps-lasers-seek-out-and-destroy-cancer-tumours&Itemid=159

[20] Targeting Tumors Using Tiny Gold Particles
http://www.sciencedaily.com/releases/2009/05/090504151454.htm

[21] The Potential Disadvantages of Nanotechnology
http://nanogloss.com/nanotechnology/the-potential-disadvantages-of-nanotechnology/